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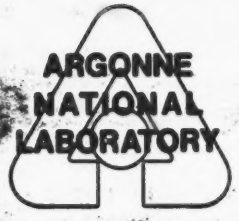
COMMIX-1A THREE-DIMENSIONAL IN-VESSEL SIMULATION OF THE FFTF THERMAL HYDRAULICS

by

S. P. Vanka, H. M. Domanus,
and W. T. Sha



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Components Technology Division

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Abstract

Three-dimensional in-vessel simulation of the FFTF thermal hydraulics has been performed with the COMMIX-1A computer code. The COMMIX-1A code employs the porous media formulation in which the concept of volume porosity, surface permeability, distributed resistance, and distributed heat source is used to model the internal structures. The governing equations of conservation of mass, momentum, and energy are solved as a boundary-value problem in space and as an initial-value problem in time. In the present report the calculated results for the steady-state reactor full-power operation are presented, and are compared with experimental measurements, where applicable. Based on the COMMIX calculations, thermal stratification is observed in the upper plenum, together with eddy-type recirculation. Comparison of measured flow rates and temperatures at selected locations has been satisfactory.

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Executive Summary

The three-dimensional steady-state in-vessel thermal hydraulics of the Fast Flux Test Facility is analyzed by the use of the COMMIX-1A computer code. The detailed geometry of the core, plenum, and in-vessel components have been modeled through the concepts of volume porosity and surface permeability. A total of 5901 computational cells have been employed.

The computed results show significant three-dimensionality in the velocity and temperature fields. In the upper plenum, temperature stratification is observed, with the interface being close to the outlet nozzles. The calculated flows and temperatures at the outlets of fuel assemblies, where possible, have been compared with measurements. Satisfactory agreement has been observed. The report presents detailed plots of velocities and temperatures and comparisons with experimental data.

1. Introduction

COMMIX-1A (Component Mixing - (1) Single-Phase Advanced Version) is a general-purpose computer code for analyzing transient three-dimensional single-phase flows. The complete details and the capabilities of this computer code have been reported earlier by Sha et al. [1,2]. Briefly, the computer code solves the transient three-dimensional Navier-Stokes and energy equations for single-phase flows in Cartesian or cylindrical polar-coordinate systems. It also has a unique way of treating internal obstacles and porous objects through the concepts of surface permeability and volume porosity. The computer code also models the thermal-structure response to temperature and flow transients.

In the present study, COMMIX-1A has been applied to analyze the thermal hydraulic characteristics of the reactor vessel of the FFTF (Fast Flux Test Facility). The Fast Flux Test Facility, located in Richland, Washington, is a 400-MW fast breeder reactor constructed under the sponsorship of USDOE. The FFTF is a loop-type reactor system with three loops connected to the vessel. Recently, tests were conducted at the FFTF facilities to investigate the transient behavior of the reactor system following a reactor scram. One of the main observations pertinent to the present report is the occurrence of thermal stratification in the upper plenum of the reactor vessel. This stratification is important from the viewpoint of material stress and structure integrity. In the present study, detailed in-vessel calculations have been made of the FFTF with the intent of a) validating the COMMIX-1A thermal-hydraulic models by comparison of calculations with data, where applicable; and, b) providing a more detailed description of the overall flow patterns and temperatures in the vessel in regions where data are not available.

In the following sections, first a brief description of the reactor geometry is given. A brief description of the COMMIX-1A code specifying its capabilities is given in Section 3. Section 4 presents the results of the calculations for 100% power, and where applicable, comparisons have been made with experimental data. Because of the large volume of data, only a portion of the comparisons between the calculated results and the experimental measurements are presented.

2. Description of the Geometry

2.1 General

The complete details of the FFTF system have been earlier documented in the design reports of FFTF. The FSAR (Final Safety Analysis Report)[3] also contains a description of the reactor vessel and the complete plant. The following material has been excerpted from the relevant sections of the FSAR, with appropriate changes for consistency and sequence with the rest of the material in this report.

The primary function of the reactor is to provide the capability of testing candidate materials for the fast breeder program in environments approximating those to be found in commercial fast breeder power reactors. The core provides the neutron flux, establishes the power density and operating temperature, and houses test specimens.

The reactor system components are:

1. Driver Fuel Assembly

2. Nuclear Control Components
   a. Control Rod Components
   b. Control Rod Drive Mechanism (CRDM)
   c. CRDM Shield Plug and Enclosure Cap
   d. Control Rod Disconnect Driveline
   e. Absorber Assembly

3. Open Test Assemblies

4. Core Special Assemblies
   a. In-Core Shim Assembly
   b. Simulated Core Assembly
   c. Materials Surveillance Assembly

5. Radial Reflector

6. Core Radial Restraint

7. Radial Shield

8. Core Support Structure

9. Instrument Tree

10. Low Level Flux Monitor (Mechanical)

11. Baffle/Liner Interface Seal

12. Horizontal Baffle

The assembly of these components within the reactor vessel is shown in Fig. 1. The initial core has an active height of 0.9144 m (36 in.), a volume of 1.034 m^3, and at the design power of 400 MWt has a peak flux of 7 x

10^{15} n/cm^2-sec. The average fuel burnup is 45,000 MWd/MT (and maximum burn up = 80,000 MWd/MT) at nominal coolant temperatures of 315.5°C (600°F), inlet, and 482.2°C (900°F), core outlet. The initial core design is capable, also, of operating at nominal core coolant inlet and outlet temperatures of 414°C (777°F) and 580.5°C (1077°F), respectively, at reduced burnup.

The driver fuel is composed of mixed plutonium-uranium oxides (PuO_2/UO_2), with compositions of 22.43 and 27.37 wt% Pu/(U + Pu) for the inner and outer enrichment zones, respectively. Natural uranium is used, and the plutonium used has a fissile content of about 88 wt% (Pu-239 + Pu-241). Future reload driver fuel may deviate from these compositions because of changing operational requirements and feed-material assays.

2.2 Core Arrangement

The reactor core consists of a hexagonal array of vertical elements arranged as shown on the Core Map (Fig. 2). The initial active core, which consists of 91 positions, is surrounded radially by a reflector region, containing three rows of reflector assemblies with additional locations available in the inner row (Row 7, where fixed shim or additional movable control-rod assemblies may be inserted in the future), and the radial shield region, which is composed of shield segments. All these components are supported and located by the core support structure. The core restraint mechanisms, which are mounted on the core barrel, position the core and control-core configuration including the reflector region. In-vessel storage for irradiated fuel assemblies and other components is provided between the core-support-structure barrel and the reactor-vessel thermal liner. The instrument trees are hung from plugs in the vessel head and laterally supported by the core-support-structure barrel.

Each of the core-basket lattice positions that comprise the hexagonal core and reflector regions have the same nominal lattice spacing of 0.120 m (4.730 in.) (room temperature). The available eight test positions are located in a Y-shaped pattern of three radial corridors extending from the center of the flats of the hexagonal arrangement. Assemblies in these corridors extend to the reactor head for contact instrumentation (open test assemblies) and optional sodium coolant inlet/outlet connections to a closed loop system (closed loop in-reactor assemblies). Other driver fuel positions in the core may also be used as test positions. Contact instrumentation, however, is not possible in these positions. The trisected design is compatible with the refueling system, which uses three in-vessel handling machines, each of which services a 120° segment of the core.

2.3 Thermal/Hydraulic Characteristics

2.3.1 Core Assembly Orificing

Core assembly orificing is used for thermal-performance optimization and to limit the maximum cladding temperature. The reduction in cladding temperatures is accomplished by increasing the flow in the high-power assemblies above the average and reducing the flow in the lower-power assemblies below the average while maintaining the same total core flow rate. The method used to orifice the FFTF fuel assemblies adjusts the flow rate so that the maximum steady-state cladding inside temperature which occurs in each

orificing zone is as nearly equal as possible.

The three orificing zones used are:

1. Hexagonal Rows 1 to 4 of the core
2. Hexagonal Row 5
3. Hexagonal Row 6

Orificing is also used to regulate the flow to the control and safety rods, fixed shims, reflectors, shielding, and vessel thermal liner.

2.3.2 Coolant Flow Path (Fig. 3)

The coolant flow enters the reactor vessel through three 0.4064-m (16-in.)-ID inlet nozzles. The nozzles are spaced 120° apart and are located near the bottom of the reactor vessel. From the nozzles, the coolant enters a large inlet plenum, where the coolant is mixed before flowing through a flow-distribution system to the reactor core and outlet plenum. Finally, the coolant exits through three 0.711-m (28-in.) dia. outlet nozzles, which are spaced 120° apart.

2.3.3 Outlet Plenum

To ensure that fuel assemblies are fully immersed in sodium at all times while in the reactor vessel, the outlet plenum has been made deep enough so that the distance from the top of the core to the pool surface, 4.877 m (over 16 ft.), is greater than the sum of the length of a fuel assembly, 3.66 m (12 ft.), and the clearances needed to handle an assembly. The design requirements placed on the outlet plenum have led to a plenum design which contains a large volume of sodium. This large volume of sodium ensures that thermal transients at the core outlet will be significantly attenuated before they affect the vessel outlet nozzles.

In addition, the outlet plenum design meets two requirements: 1) Cover-gas entrainment is limited by the use of a horizontal baffle below the coolant surface, and 2) adequate coolant volume is provided to fill the guard vessel in the event of a sodium leak, while still maintaining the reactor-coolant level above the minimum safe level.

2.4 Driver Fuel Assembly

The fuel assembly is basically a hexagonally shaped component, 0.116 m (4.575 in.), across outside flats and 3.657 m (12 ft.) long. The assembly comprises: a bundle of 217 fuel pins, 0.584-cm (0.230-in.)-OD, and containing the mixed oxide (PuO_2/ UO_2) pellets; a surrounding duct tube; and lower and upper end hardware. The pins are positioned in a triangular lattice and spaced by a 0.142-cm (0.056-in.)-dia. helical-wrapped wire. The fuel assembly is located radially by the core support structure and it uses a hydraulic balance holddown system to maintain a fixed axial position during reactor operation.

2.5 Reactivity Control

The neutron flux level in the FTR is controlled by vertical movement of neutron-absorbing assemblies into and out of the core. The absorber assembly is a bundle of 61 stainless steel-clad B_4C pins (natural boron) housed in a duct similar to that of the driver fuel assembly. The reactor has the capability of accommodating up to nine in-core control rods and nine peripheral control rods. The initial core uses three in-core safety rods and six control rods, plus additional fixed shim control rods in the form of in-core shim assemblies and fixed shim assemblies.

2.6 Radial Reflector

The radial reflector consists of two types of reflector assemblies: inner and outer. The inner assemblies have an external hexagonal configuration and are the same length, 3.657 m (144 in.), as the driver fuel assembly and are supported by the core basket. The outer assemblies are about 0.3048 m (12 in.) shorter than the inner assemblies, 3.349 m (131.85 in.) and are supported by the inner radial shield assembly. The reflector assemblies are composed of a section of Inconel 600 and upper and lower shield sections of stainless steel. The Inconel section and the upper shield sections consist of blocks stacked on a vertical array of parallel coolant and structural tubes.

2.7 Radial Shield

The radial shield consists of six inner shield blocks and six outer shield blocks, which are arranged around the periphery of the radial reflector region. The inner and outer shield blocks are composed of vertical-standing stainless steel plates.

2.8 Core Support Structure

The core support structure positions the core components within the reactor vessel. The support structure is welded to the reactor vessel and is composed of the lower structure, support skirt, core barrel, core basket, horizontal thermal baffle, and in-vessel storage. The core basket is centrally located in the core support structure. The core barrel is welded to the lower structure and provides lateral support for the radial shield, the core restraint mechanisms, and the instrument tree. The horizontal thermal baffle on top of the core barrel provides thermal protection to the lower structure and the core barrel from the outlet plenum coolant. In-vessel storage is provided in three sections of the annular region between the core barrel and the reactor-vessel thermal liner. Each storage region provides 19 natural-convection-cooled receptacles for core components, and one transfer port position for the core component pot.

The core basket is centrally located within the core support structure and provides vertical support for the driver fuel assemblies, test assemblies, absorber assemblies, and inner reflector assemblies. The basket is a closed cylinder with 151 tubular receptacles connecting the upper and lower tube sheets. The cylindrical section of the basket has twelve rectangular flow slots, fitted with flow strainers, oriented to mate with comparable slots in the core support structure. Azimuthal orientation and vertical retention is provided by a locating pin and a breech-lock-type locking ring.

2.9 Instrument Tree

The instrument tree is mounted on the reactor head and positions the core outlet instrumentation sensors above the driver-fuel assemblies (temperature and flow) and control-rod assemblies (outlet temperature) and provides secondary holddown for them. The instrument tree also positions instrumentation over control-rod fixed shim assemblies and selected reflector assemblies. All instrumentation is routed through large and small openings in the instrument-tree columns. The drive assemblies for lift and rotation of the instrument tree are located in the head compartment. Each instrument tree also contains guide tubes for six control-rod drivelines. The FTR has three instrument trees, each one covering a trisector of the core.

2.10 Horizontal Baffle

The horizontal baffle is mounted at the upper end of the core barrel and acts as a thermal insulator between the hot outlet plenum and the relatively cool fuel-storage annulus. In addition to limiting thermal conduction, the baffle limits outlet plenum sodium from flowing into the fuel-storage annulus region.

The horizontal baffle, consisting of 42 plates 0.0508 m (2 in.) thick, has trisector symmetry. Each plate is supported from a single standoff to permit unrestrained thermal distortion.

Complete details of the vessel geometry may be obtained from the design manuals and the FSAR.

3. Brief Description of the COMMIX-1A Code

The COMMIX-1A computer program is a general-purpose thermal-hydraulic code that can be employed to analyze multidimensional steady/unsteady reactor component/multicomponent fluid-flow problems. The computer program has been under development at Argonne National Laboratory under sponsorship of the U. S. Nuclear Regulatory Commission. The general background and equations solved by COMMIX-1A have been reported earlier at various instances, but notably in references 1 and 2. For completeness, we give brief details of the computer code and its capabilites.

The equations solved by COMMIX are the transient, three-dimensional forms of the equations for

a. Mass continuity,

b. Conservation of x momentum, y momentum, z momentum, and

c. Conservation of energy.

The above fluid and heat-transport equations are solved in the concept of volume porosity/surface permeability, which permits easy and realistic representation of partially open internal regions. The effects of heat capacity of internal structures are explicitly taken into account.

The equations are solved by a finite-difference calculation procedure originally based on the IMF procedure of reference 4, but improved for faster and more efficient computations. The version of the COMMIX code series currently used is VER 3.0, which is based on an explicit time-marching procedure. Advanced versions shortly to be released (VER 6.0) have a fully implicit time-differencing option.

In addition to the above features, COMMIX has input features which permit easy simulation of complex geometries. As a result, COMMIX has been applied to study thermohydraulic conditions in reactor components such as plena, reactor cores, pipes, and heat exchangers, and in combinations of these components.

4. Steady-State Behavior of the FFTF for 100% Power

The main aim of the present study is to calculate the reactor-vessel thermal hydraulics during the natural-circulation period following reactor scram. Calculations have been first made of the steady-state operating conditions at 100% power. The transient is then initiated by prescribing the inlet flow and temperature and reactor power as functions of time. In the present report, we have described the calculations for the steady-state behavior only; the results for the transient (natural circulation) conditions will be reported in a separate report.

4.1 Details of the Computations

The reactor vessel has been modeled as a number of discrete cells. In the present calculation 5901 cells were placed in the entire flow domain. The finite-difference grid is shown in Figs. 4 (a and b). The inlet velocities and temperatures are prescribed at the three inlets to the lower plenum. At the outlets, a zero derivative boundary condition for the outlet velocity and temperature is prescribed. The internal obstacles in the plenum (IVS and Instrument Tree Stem) are modeled through prescription of appropriate volume porosities and surface permeabilities. The appendix gives the details of some of the important quantities prescribed to the code.

4.2 Presentation of Results

The coolant flow path has been earlier sketched in Fig. 3. As expected, the output from the COMMIX code displays a similar flow path. The inlet flow enters the inlet plenum, flows upwards to the core basket and the shield, and subsequently enters the outlet plenum. There are three outlets located 120° apart in the outlet plenum.

The output from the calculations is a detailed description of the velocities and temperatures at 5901 nodes in the reactor vessel. Since it is difficult to present all this information concisely, we have plotted the flow patterns in various planes (axial and azimuthal) to illustrate the flow distribution. These are shown in Figs. 5 (a-ℓ) and 6 (a-n). The comparison of calculations with experiments at steady state have been made of flow rates and temperatures at selected locations. These are tabulated in Tables 1, 2, and 3. It is seen that, but for minor differences, the agreement is satisfactory between experiments and calculations. The temperature contours are shown in Figs. 7 (a-ℓ) for various planes. It can be seen that there is appreciable

three-dimensionality in the flow and temperature, notably because of differences in power output and the locations of outlet nozzles. There is also an effect due to the presence of the internal obstacles such as the Instrument Tree Stem and the In-Vessel Handling Machine Stem.

4.3 Discussion of Results

From the results presented in earlier figures, the following phenomena are worth observation: First, there is significant three-dimensionality in the flow, especially above the core. There are secondary vortex-type flows in the lower plenum. Above the core, the flow exiting the core fans out at the top, and as seen in Fig. 6(n) (K = 18), flows radially outwards to the outlet. In the r-z planes, a vortex flow is set up with downward flow near the outer wall, and upward flow at the core.

The temperature contours show temperature stratification below the level of the outlet nozzles. The low temperatures reflect the cold flow exiting the reflectors, liner, and the shield. The hot fluid represents the core exit flow. Stratification occurs near (or at) the outlet, and as it can be seen in the isotherms, there is a significant temperature gradient at and near the outlet nozzles.

The tabulated temperatures show good agreement between calculated and experimental data, except for the temperature measured by the PTP (Proximity Test Plug). The discrepancy may be due to inadequate mixing of the hot inner fluid with the colder fluid from adjacent (row 3) assemblies. The present model employs very coarse mesh and also does not exactly model the flow paths in the instrument-tree tubes. The calculated results can be improved by rigorously modeling the geometry just above the core with finer computational mesh. We have, however, accounted for the gaps between the top of the fuel assemblies and the bottom of the instrument-tree tubes. We plan to repeat the calculations at a later date after feedback is received from readers.

5. Summary

We have performed three-dimensional multicomponent thermal-hydraulic calculations in the reactor vessel of the Fast Flux Test Facility. The calculations have been performed by the COMMIX-1A computer code. Based on the calculated results, we conclude that a reasonable agreement with experimental data, where applicable, has been attained. Temperature stratification is observed with the interface being close to the outlet nozzles.

6. Acknowledgment

We are indebted to Drs. R. Stover, W. T. Nutt, and H. Johnson of Westinghouse Hanford Engineering Development Laboratory for their help in providing information on the FFTF. We are also indebted to Drs. R. T. Curtis, C N. Kelber and Mr. P. M. Wood of the U. S. Nuclear Regulatory Commission for their support, without which this work would not have been possible.

7. References

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2. W. T. Sha, "An Overview on Rod-Bundle Thermal-Hydraulic Analysis," Nucl. Eng. Des. 62, (Dec 1980).

3. "FFTF Final Safety Analysis Report," Hanford Engineering Development Laboratory (1975).

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APPENDIX

IMPORTANT INPUT DATA FOR FFTF SIMULATION

A.1 Dimensions

The dimensions were obtained either from the FSAR or from the design drawings obtained from HEDL. It is not possible and also not relevant to list all design dimensions that were used to simulate the geometry. However, we shall mention below the most important dimensions, which will enable the reader to obtain a picture of the facility. A listing of the input description to COMMIX-1A is also enclosed at the end of this appendix.

Vessel Radius	2.911 m
Vessel Height (considered for present calculations)	12.04 m
Inlet-pipe diameter	0.4064 m (16 in.)
Outlet-pipe diameter	0.7112 m (28 in.)
Number of pins per assembly	217
Pin diameter	0.00584 m (0.230 in.)
Number of assemblies (including nonfueled)	91

A.2 Flow Rates and Tempeatures

Total inlet flow	2203 kg/s (40,330 gpm)
Inlet temperature	360°C
Outlet temperature	503.3°C

A.3 Boundary Conditions

Inlet	Prescribed velocity and temperature
Outlet	Zero gradient on outlet velocity and temperature
Walls	Adiabatic

A.4 Finite-Difference Grid

The finite-difference grid consisted of 5901 cells, with 18 axial partitions, 15 radial partitions, and 24 azimuthal partitions. The finite-difference grid is sketched in Fig. 4.

A.5 Input Data Listing

A listing of the complete data is enclosed. The data consist of the grid, the surface identifications, the force structures, thermal structures, surface permeabilities, and volume porosities.

Table 1. COMPARISON OF STEADY-STATE FUEL-ASSEMBLY OUTLET TEMPERATURES AND FLOWS†

CELL (I,J) (r,θ)	CALCULATED FLOW (gpm)	MEASURED FLOW (gpm)	CALCULATED TEMPERATURE (°C)	MEASURED TEMPERATURE (°C)
1,1*	164.1	166.7	541.9	547.9
1,2	158.1	155.4	550.1	548.3
1,10	157.8	164.2	544.7	545.4
2,7	436.9	437.5	515.7	526.8
2,8	436.9	425.0	515.3	527.3
2,10	535.9	542.5	514.2	514.4
2,12	536.0	537.2	514.6	512.3
3,2	265.2	256.2	511.2	512.7
3,5	265.1	256.2	510.4	514.9
3,9	529.5	522.5	526.6	531.0
3,12	264.4	263.7	502.7	504.9

*FOTA

† The flows and temperatures are measured in instrument-tree guide tubes (approximately 0.3 m long) located above the assemblies.

Table 1 (Contd.) COMPARISON OF STEADY-STATE FUEL-ASSEMBLY OUTLET TEMPERATURES AND FLOWS

CELL (I,J) (r,θ)	CALCULATED FLOW (gpm)	MEASURED FLOW (gpm)	CALCULATED TEMPERATURE (°C)	MEASURED TEMPERATURE (°C)
3,15	528.3	520.0	525.0	517.4
3,18	265.1	270.0	510.5	504.7
3,24	529.7	520.0	525.7	528.2
4,1	522.9	547.5	530.6	522.9
4,3	521.4	540.0	521.4	512.6
4,7*	531.1	526.2	521.8	520.0
4,12	518.8	520	507.7	500.0
4,14	314.8	307.5	522.8	504.6
4,22	312.7	312.5	505.4	499.5

*FOTA

Table 2. COMPARISON OF TEMPERATURES IN OUTLET PLENUM[†]

LOCATION	CALCULATED TEMPERATURE (°C)	MEASURED TEMPERATURE (°C)
TLLM (-19'.7")	510.8	507.4
TLLM (-24'.0")	511.1	511.27
TLLM (-26'.4")	511.5	509.3
TLLM (-28'.1")	511.8	514.77
TLLM (-30'.7")	507.5	509.3
PTP	542.4	527.0
TOTAL ΔT THROUGH VESSEL	143.22	143.33
INSTRUMENT TREE STALK TEMPERATURES	436.2 (J = 6)	440.1
	436.7 (J = 14)	435.0
	436.8 (J = 22)	437.7

[†] See Fig. 4 for locations of TLLMs and PTP in R-Z and R-θ planes.

Table 3. COMPARISON OF STEADY-STATE REFLECTOR OUTLET TEMPERATURES AND FLOWS

REFLECTOR	CALCULATED FLOW (gpm)	MEASURED** FLOW (gpm)	CALCULATED TEMPERATURE (°C)	MEASURED TEMPERATURE (°C)
1703†	12.37	5.68	489.0*	495.0
1705			489.0	491.0
1707			489.0	499.0
1709			489.0	498.0
1804			432.8	451.1
2703			489.0	492.0
2705			489.0	487.0
2707			489.0	489.5
2709			489.0	489.5
2811			432.3	437.2
2901			432.6	430.0
2909			432.4	444.4
3703			489.0	495.0
3705			489.0	487.0
3707	12.37	21.0	489.0	496.0
3709			489.0	496.0
3811			432.9	447.2
3911			432.9	437.4

* Rounded-off value.

† Numbers correspond to the numbering system of the core map.

** Uncertainty exists in measured reflector flows because of low flow rates.

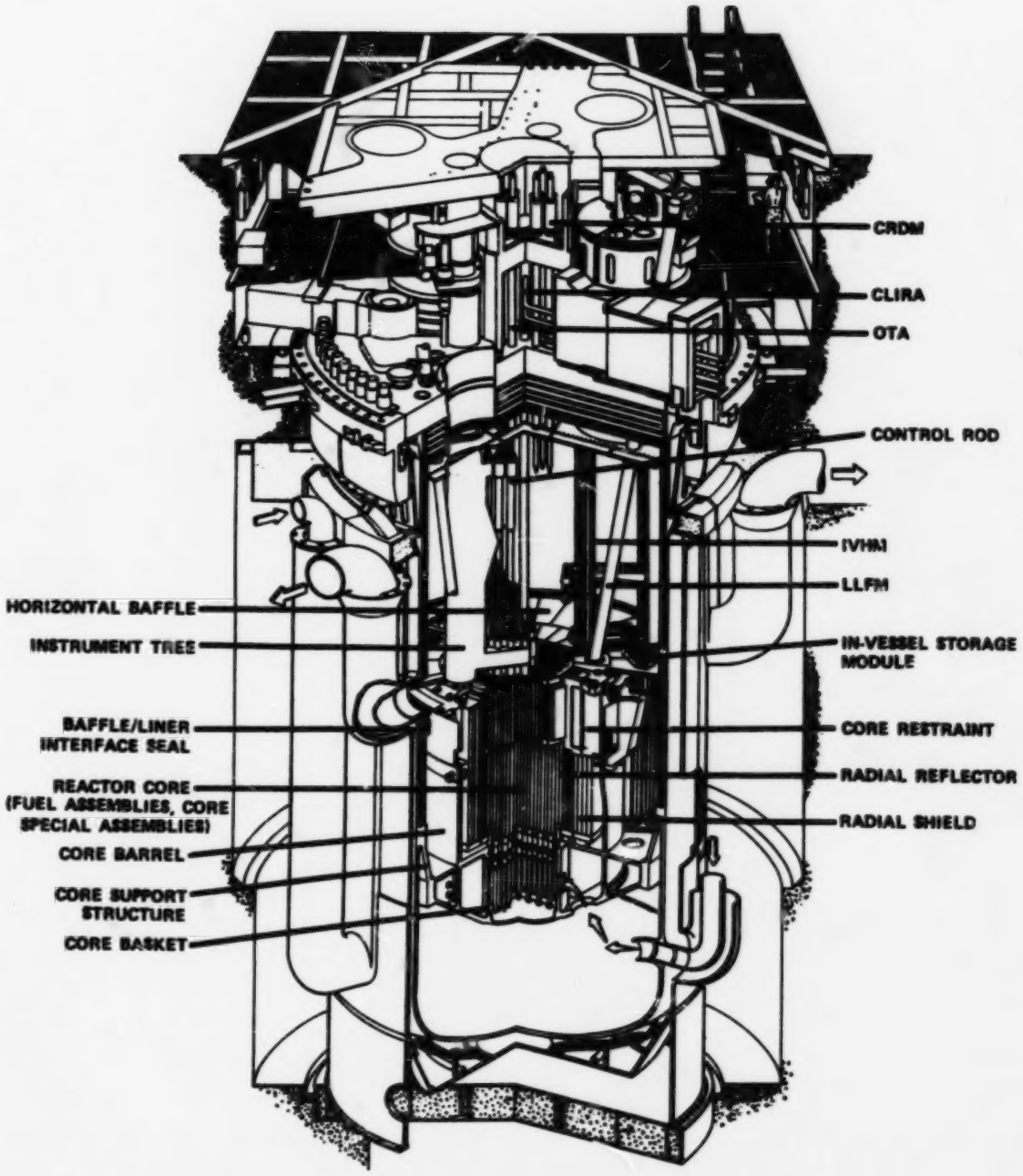

Fig. 1. Reactor Vessel and Internal Components Composite

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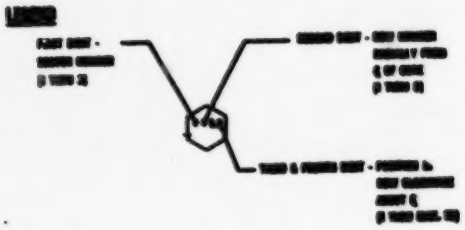

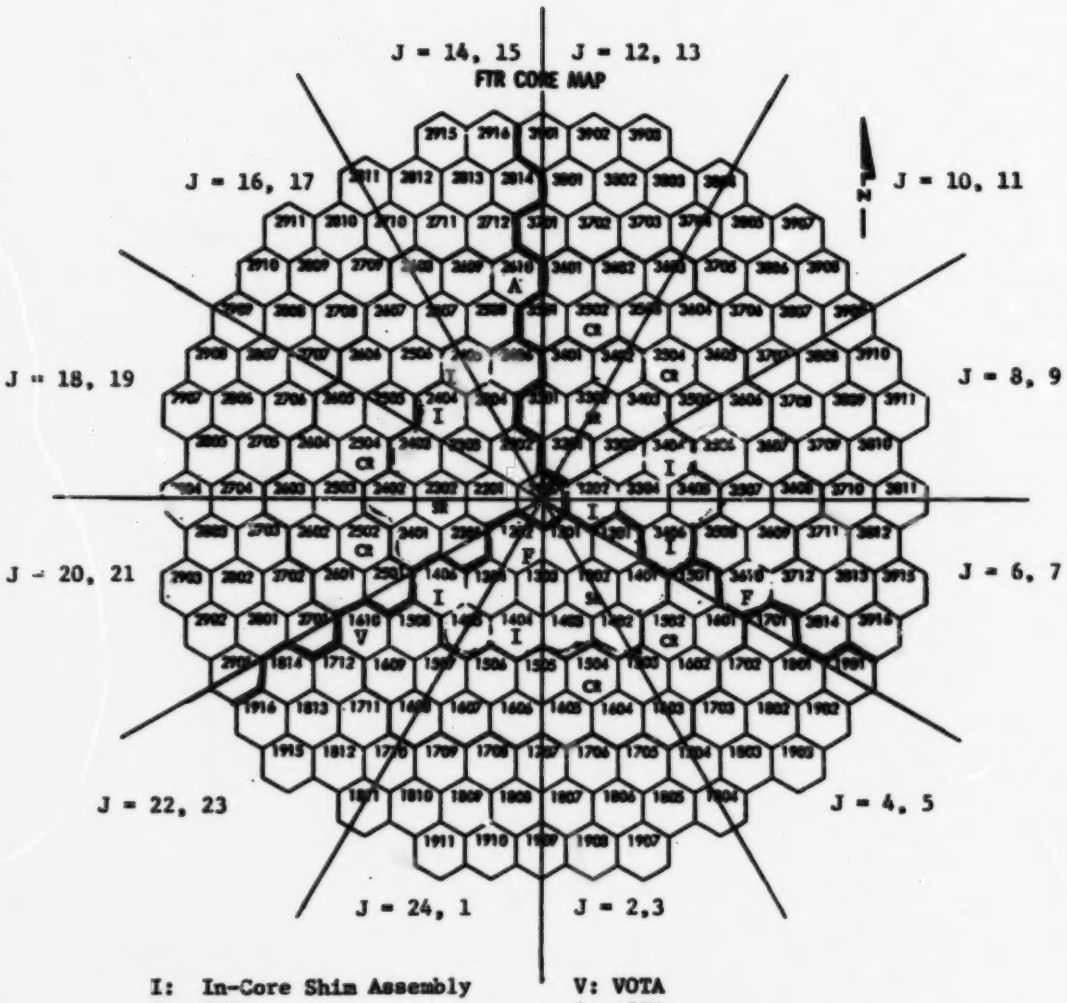

I: In-Core Shim Assembly
F: FOTA
SR: Safety Rod
V: VOTA
A: AOTA
CR: Control Rod

Fig. 2. Core Map

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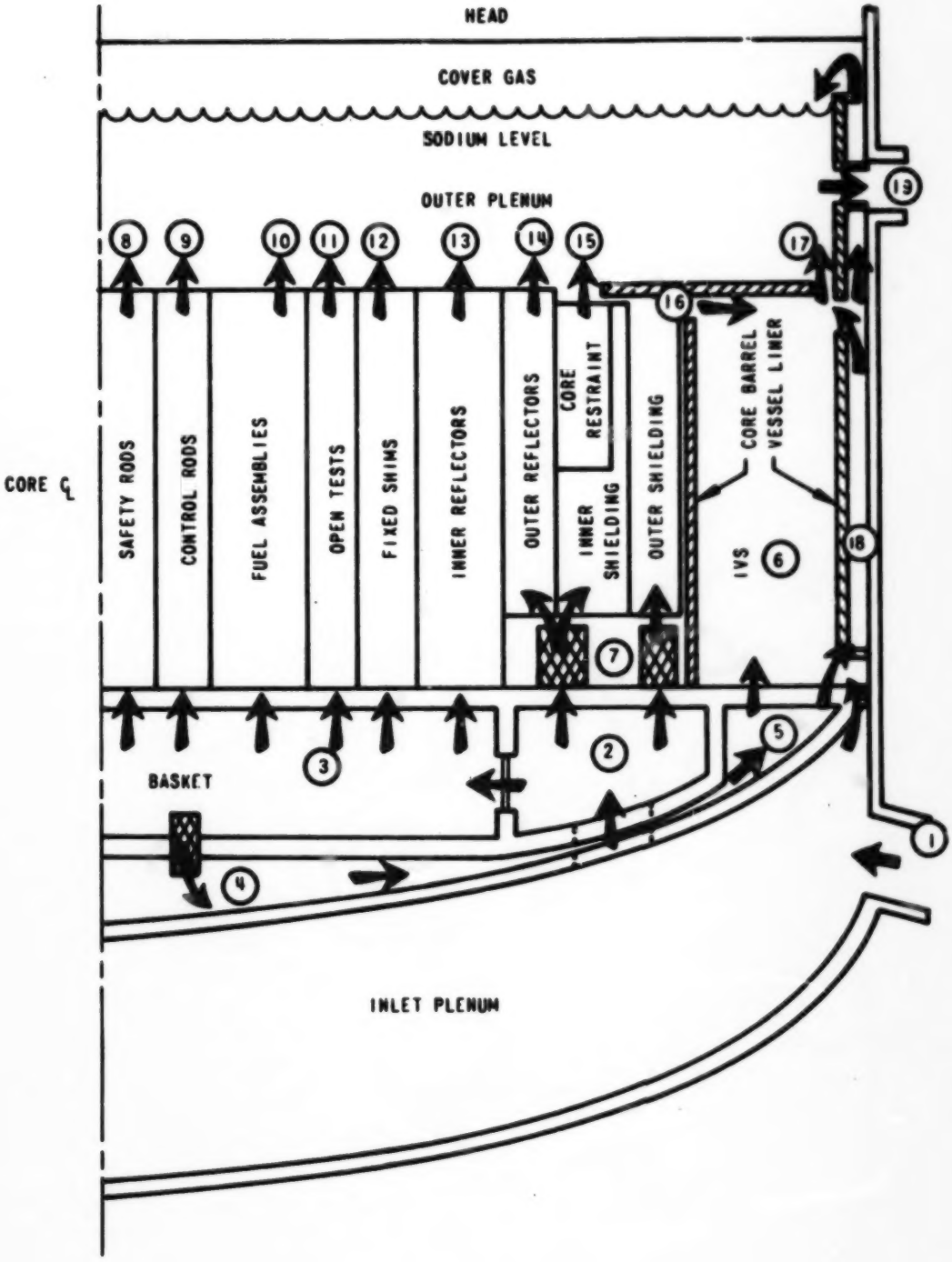

Fig. 3. Reactor Vessel Flow Distribution

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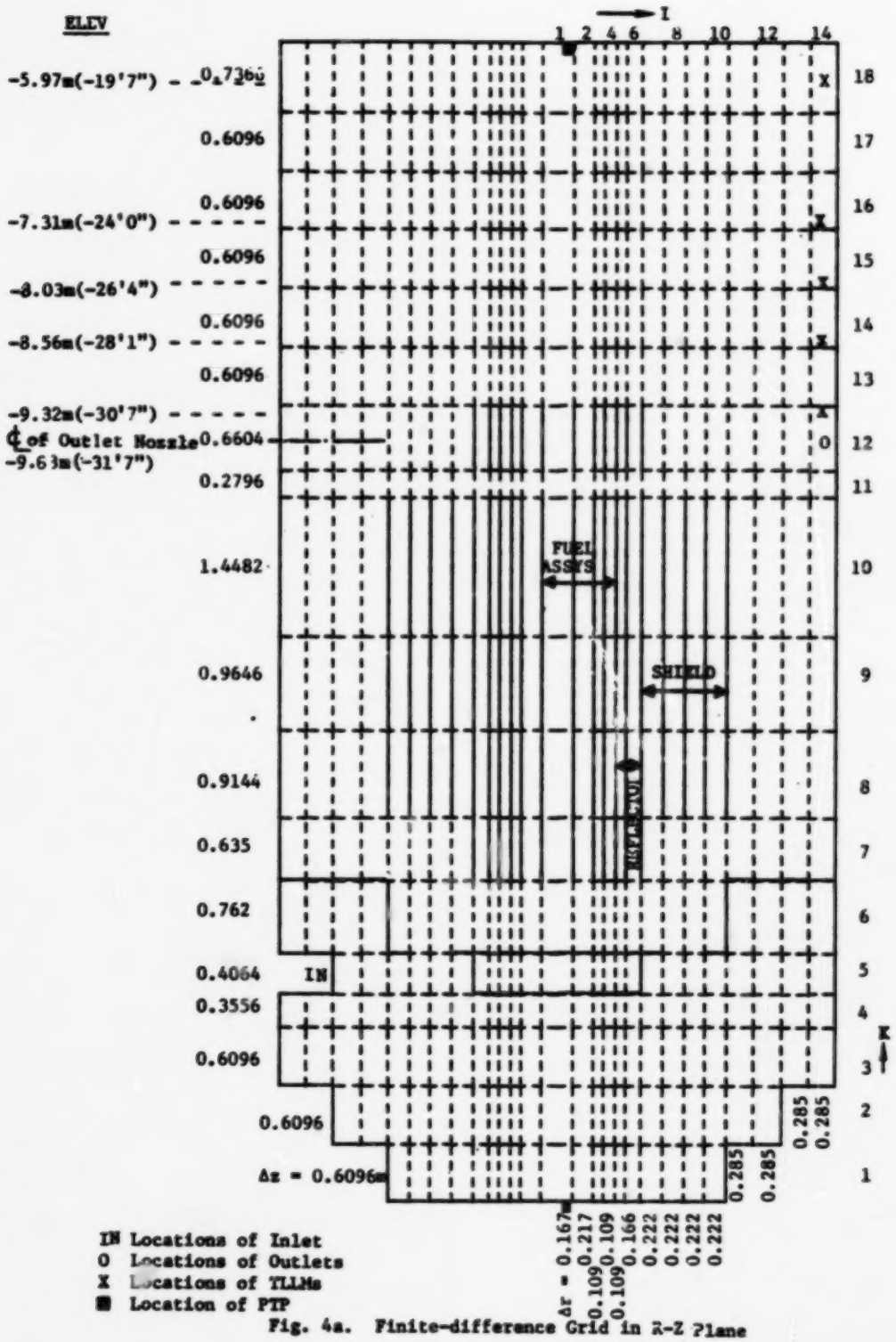

Fig. 4a. Finite-difference Grid in R-Z Plane

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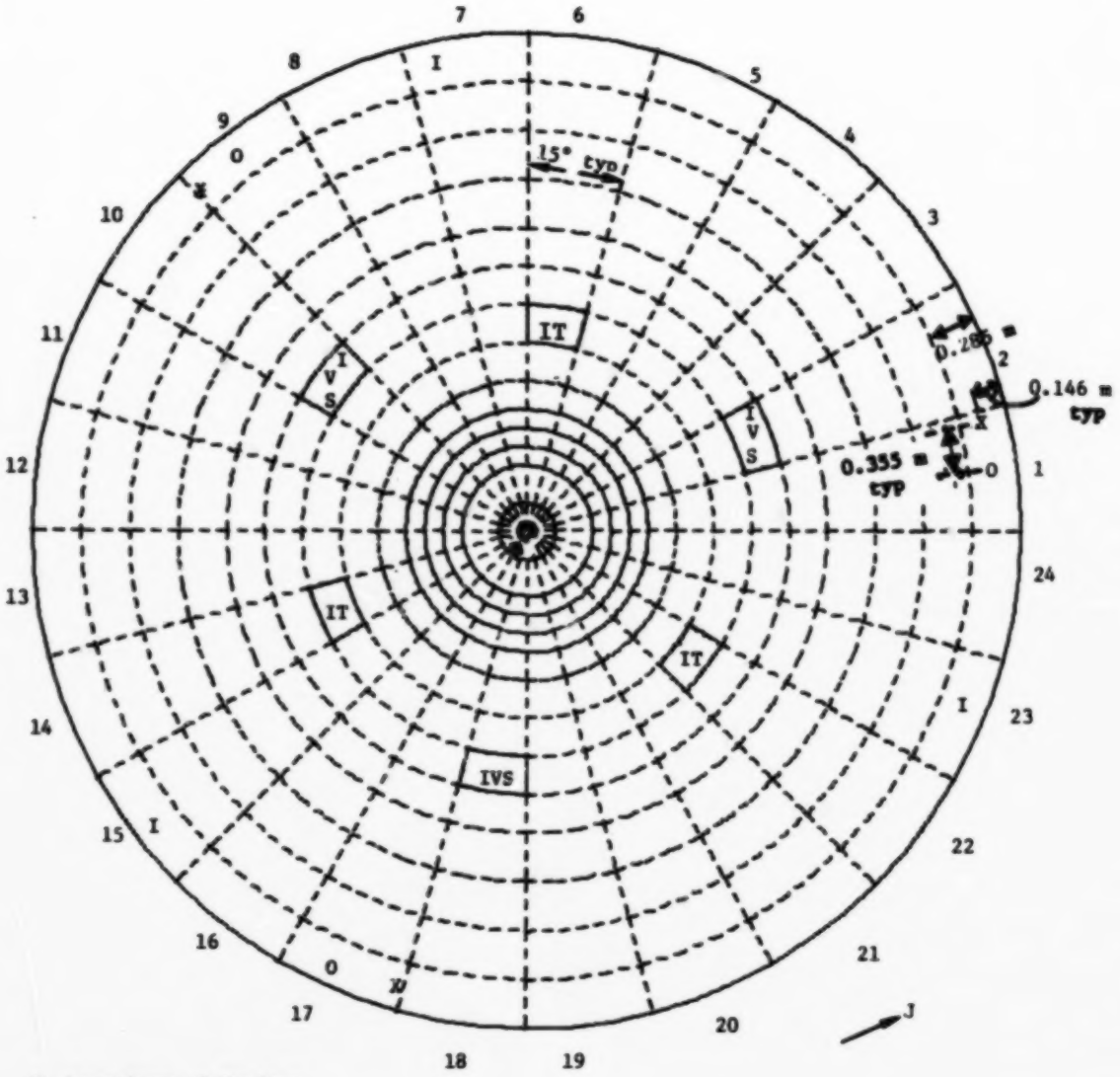

O Locations of Outlets

I Locations of Inlets

X Locations of TLLMs

● Location of PTP (above fuel assembly 2202)

Fig. 4b. Finite-difference Grid in R-θ Plane

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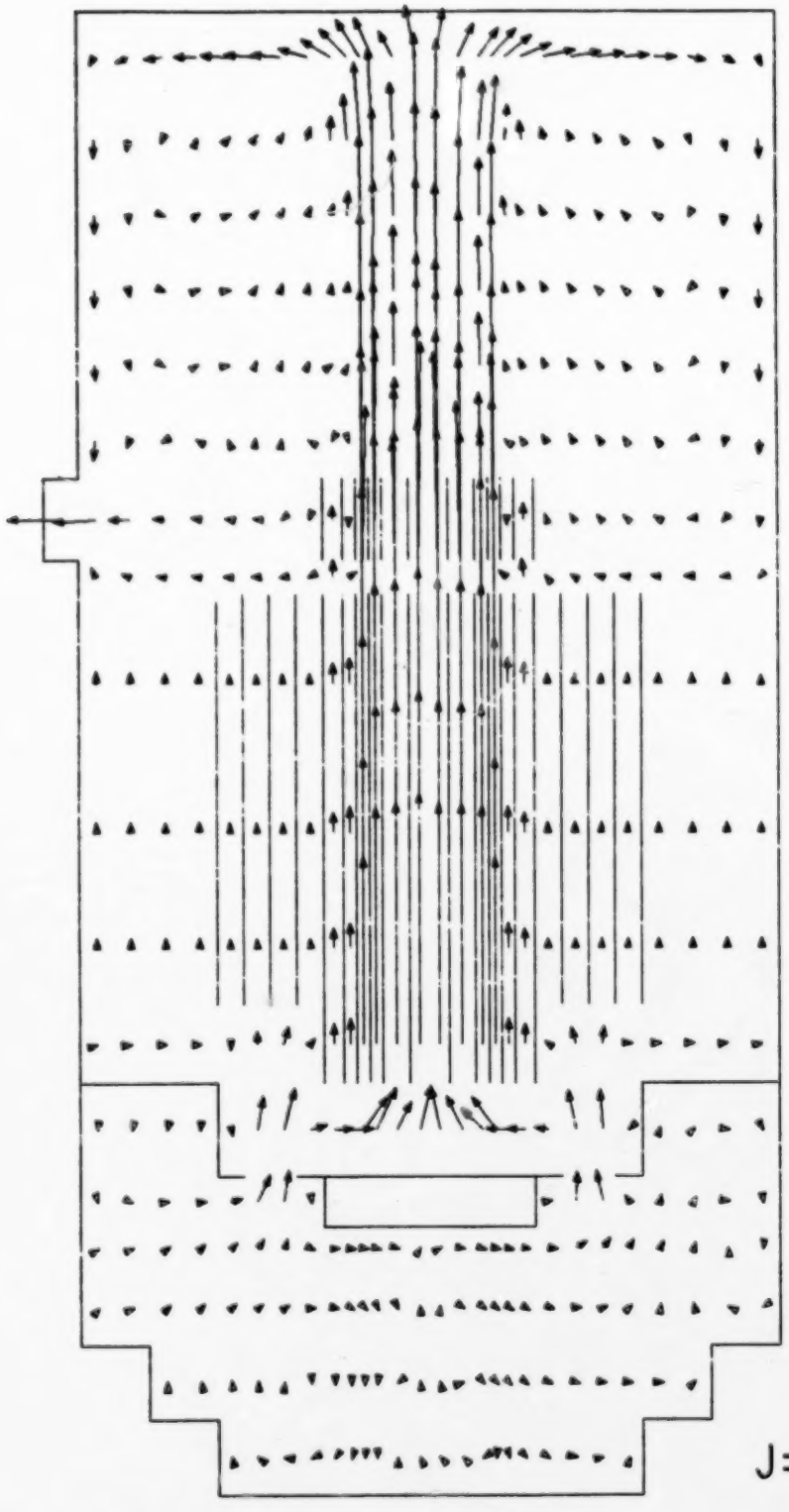

Fig. 5(a) Velocity Vectors in R-Z Plane

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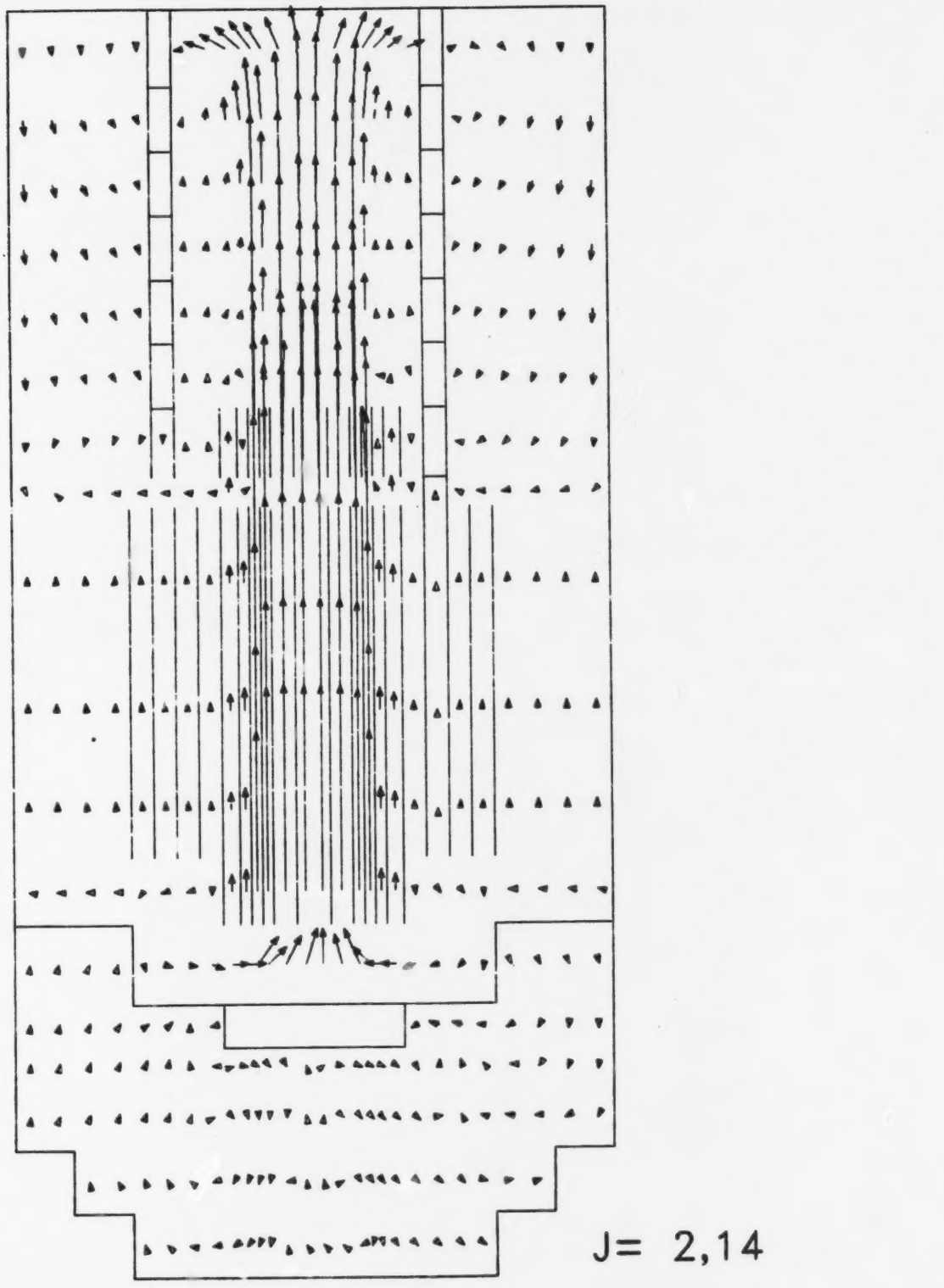

Fig. 5(b) Velocity Vectors in R-Z Plane

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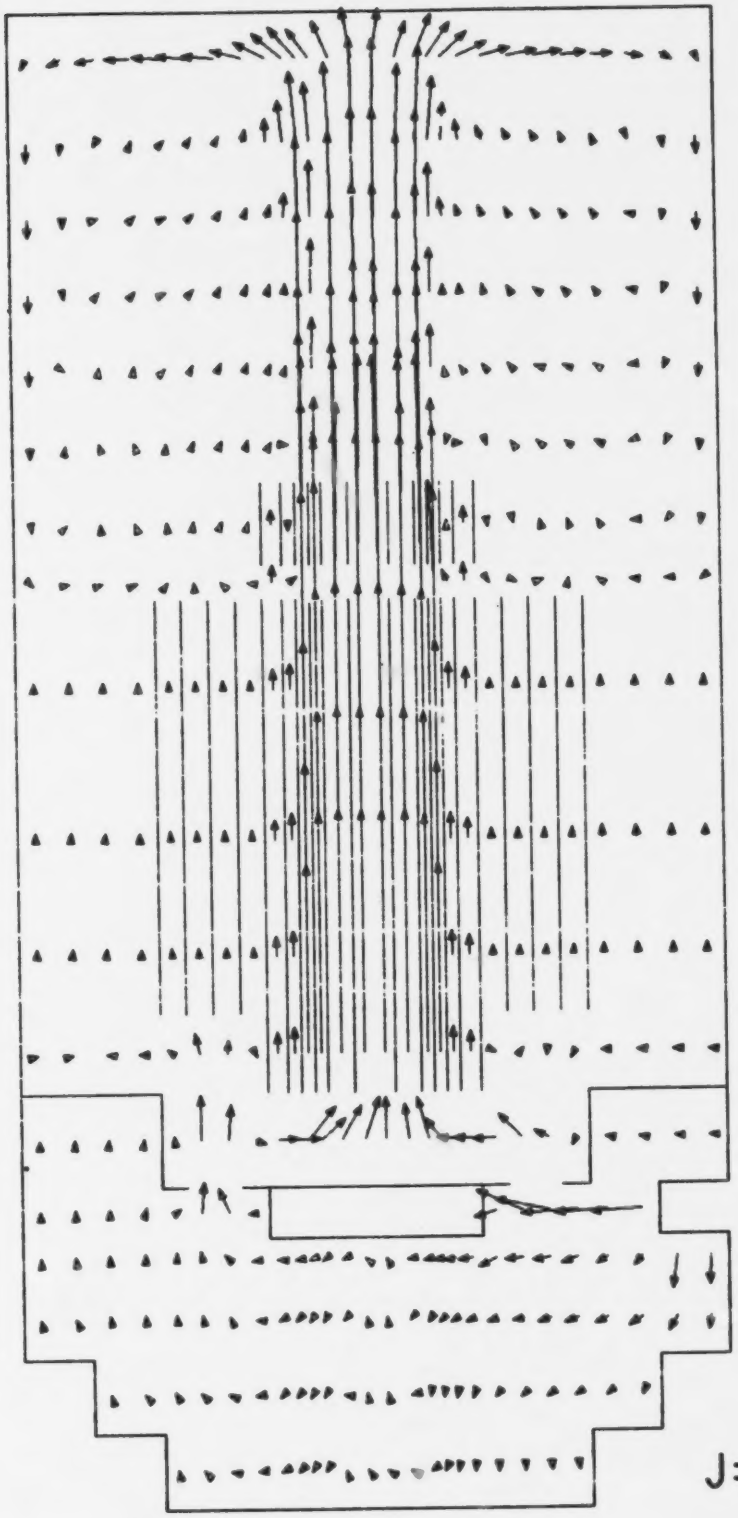

Fig. 5(c) Velocity Vectors in R-Z Plane

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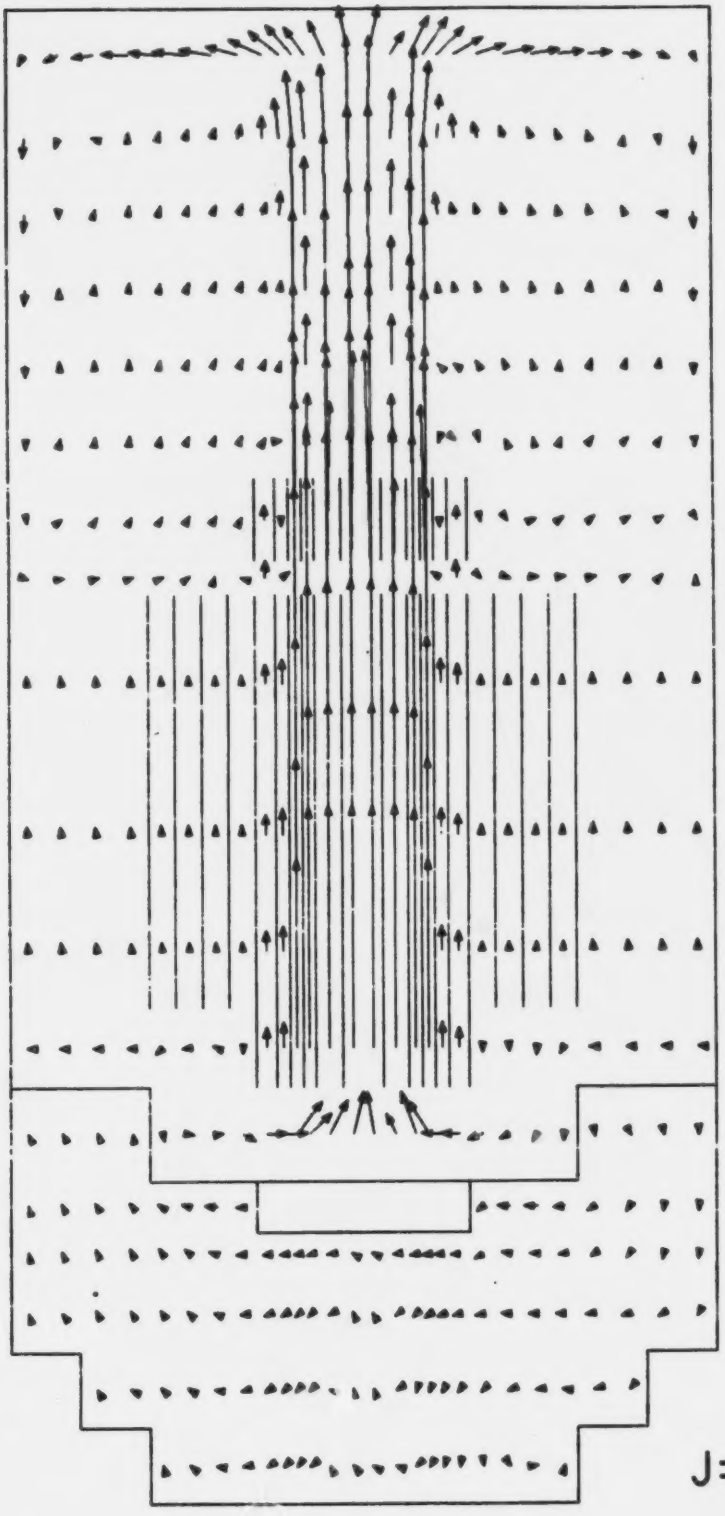

Fig. 5(d) Velocity Vectors in R-Z Plane

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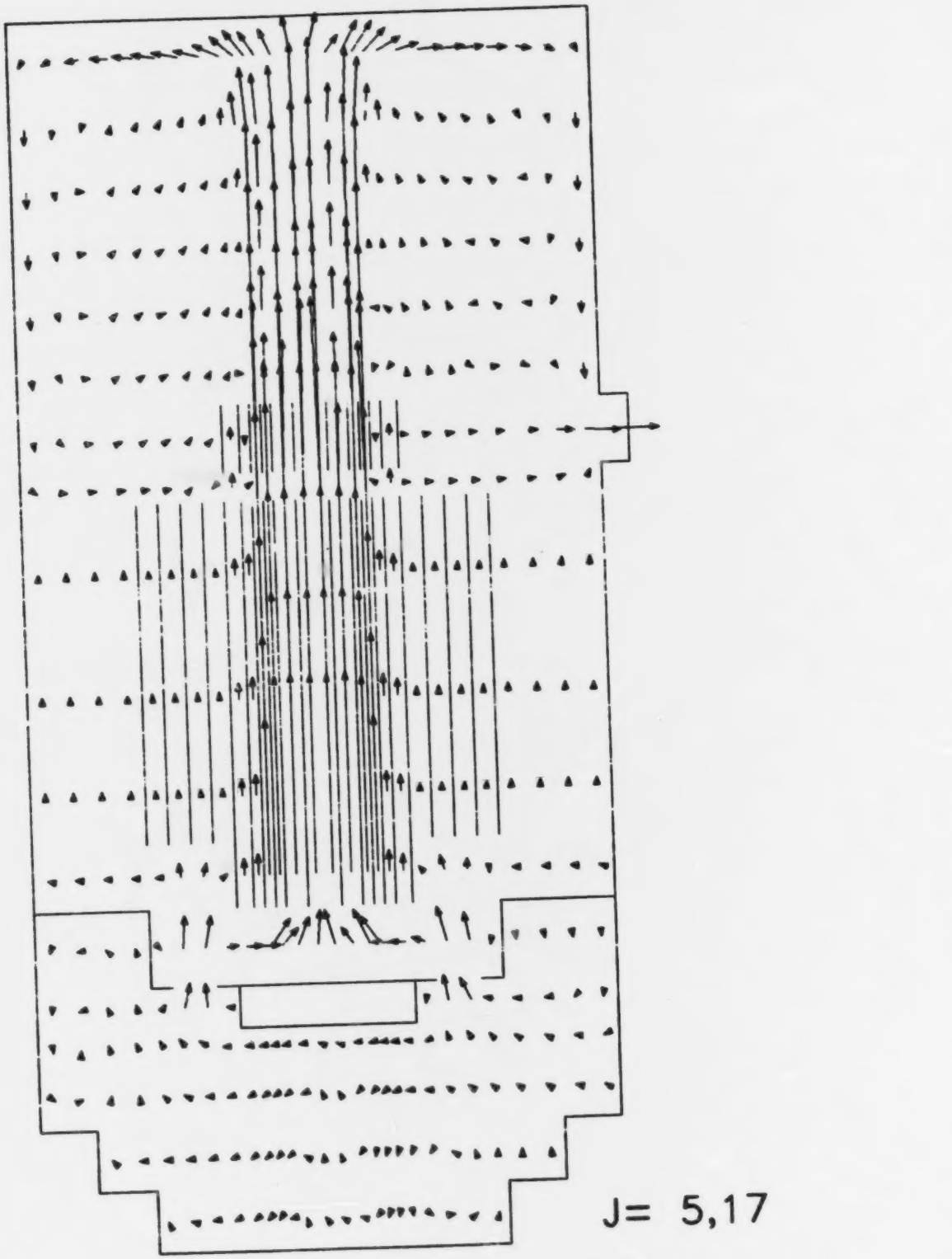

Fig. 5(e) Velocity Vectors in R-Z Plane

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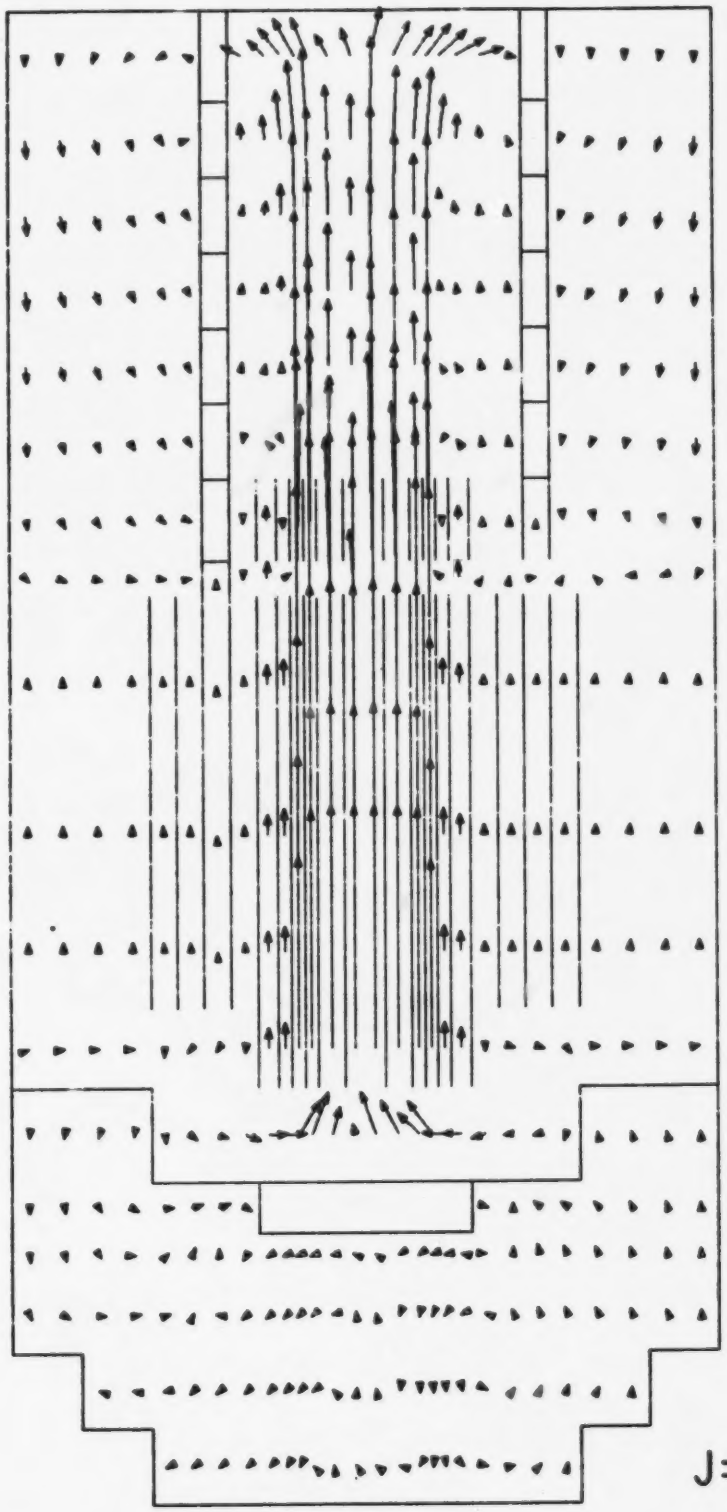

Fig. 5(f) Velocity Vectors in R-Z Plane

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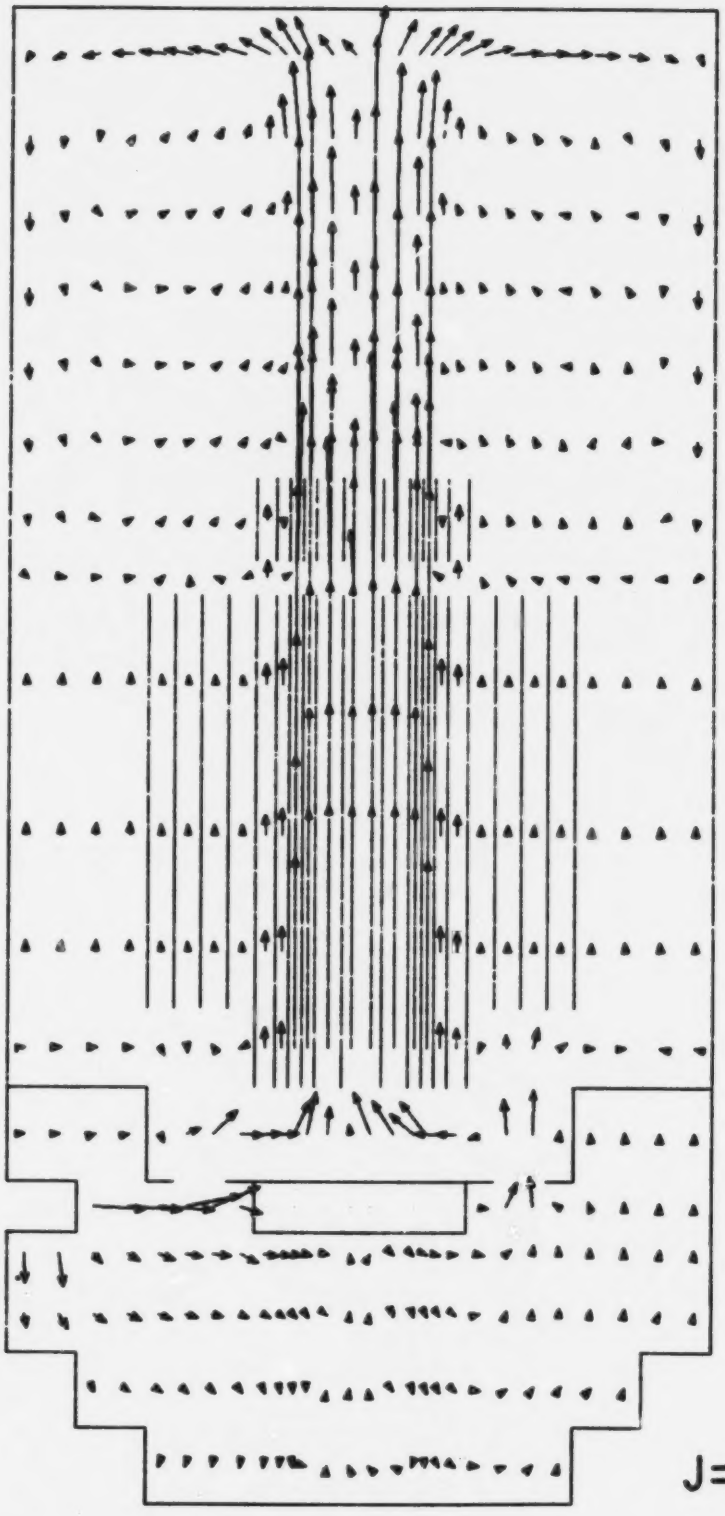

Fig. 5(g) Velocity Vectors in R-Z Plane ⟶ 3.75m/s

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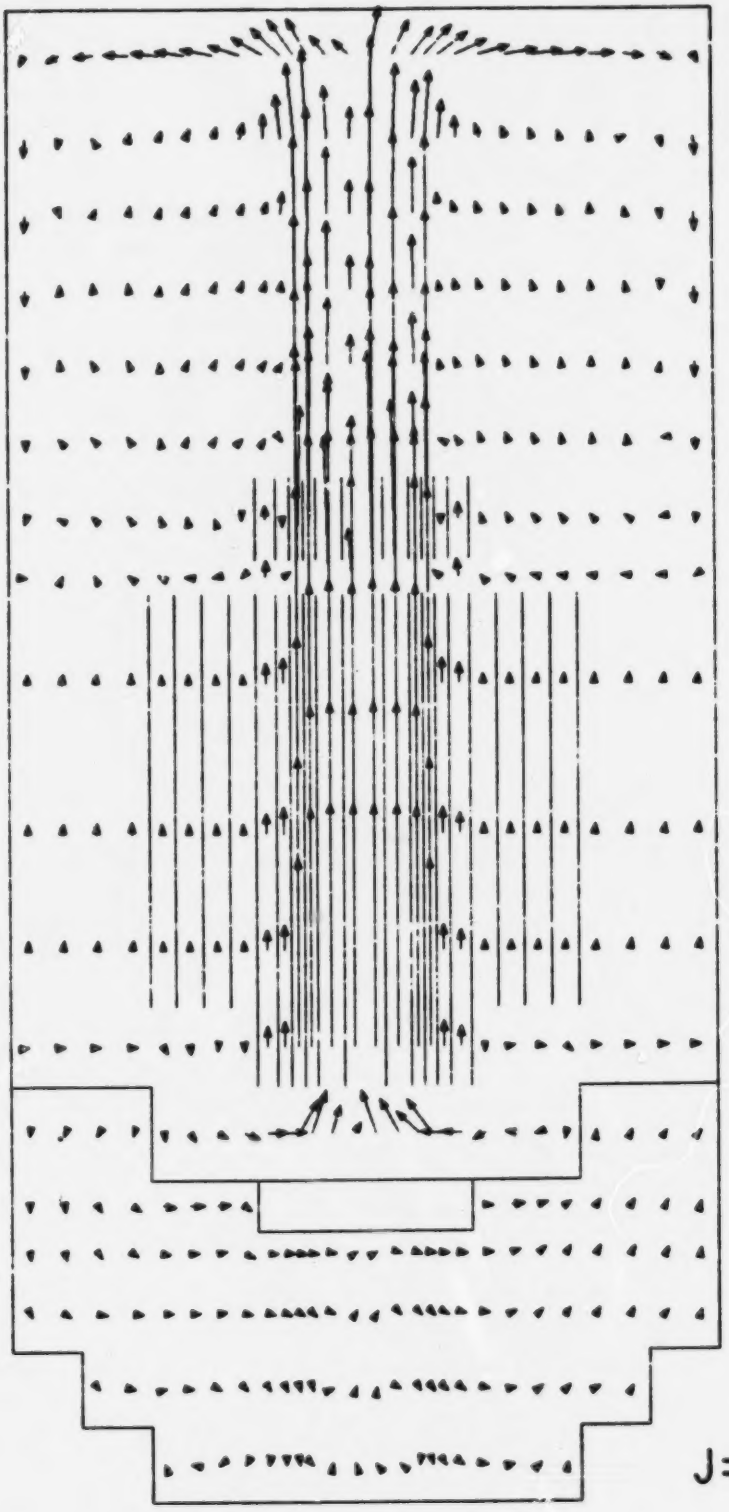

Fig. 5(h) Velocity Vectors in R-Z Plane

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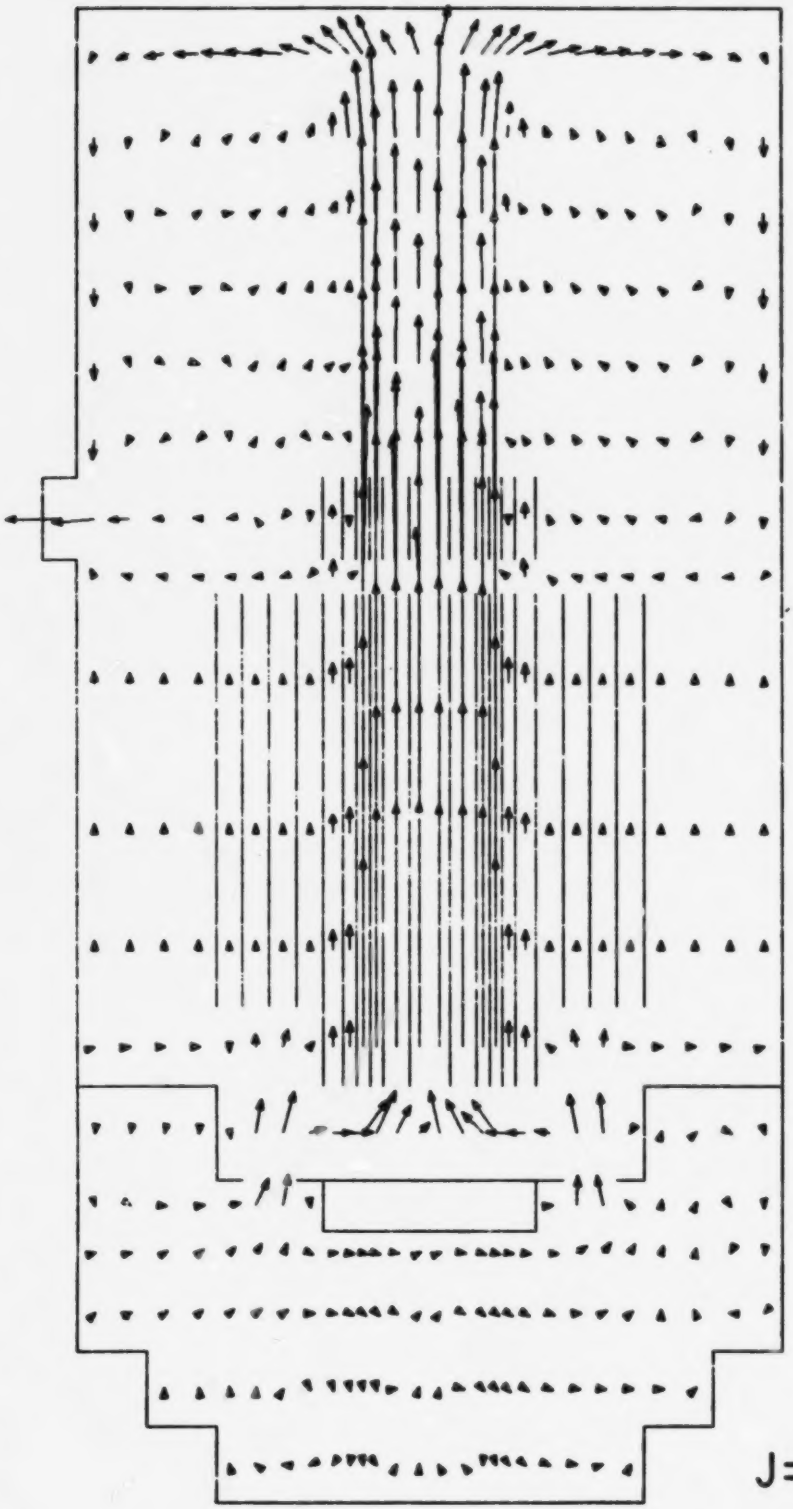

Fig. 5(i) Velocity Vectors in R-Z Plane

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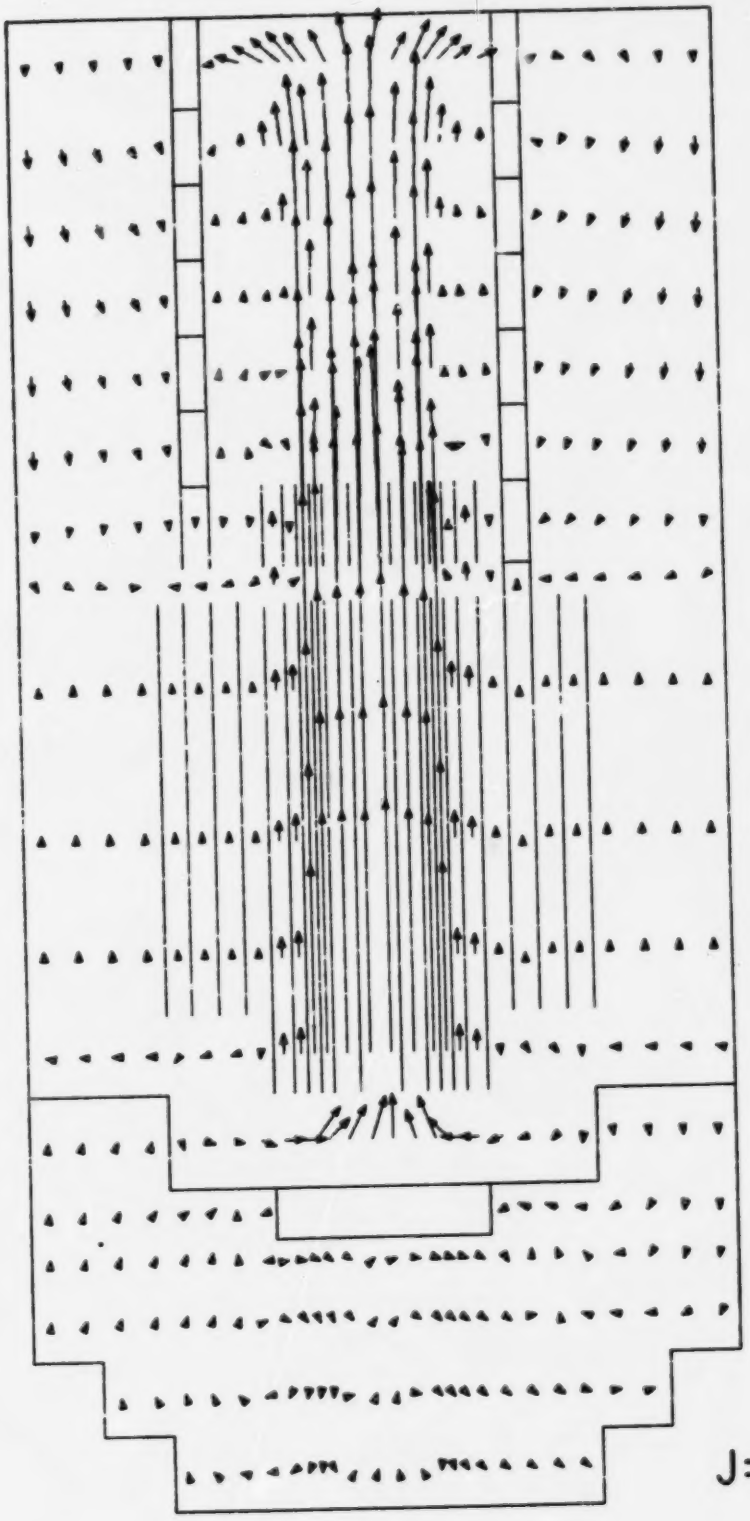

Fig. 5(j) Velocity Vectors in R-Z Plane ⟶ 3.75m/s

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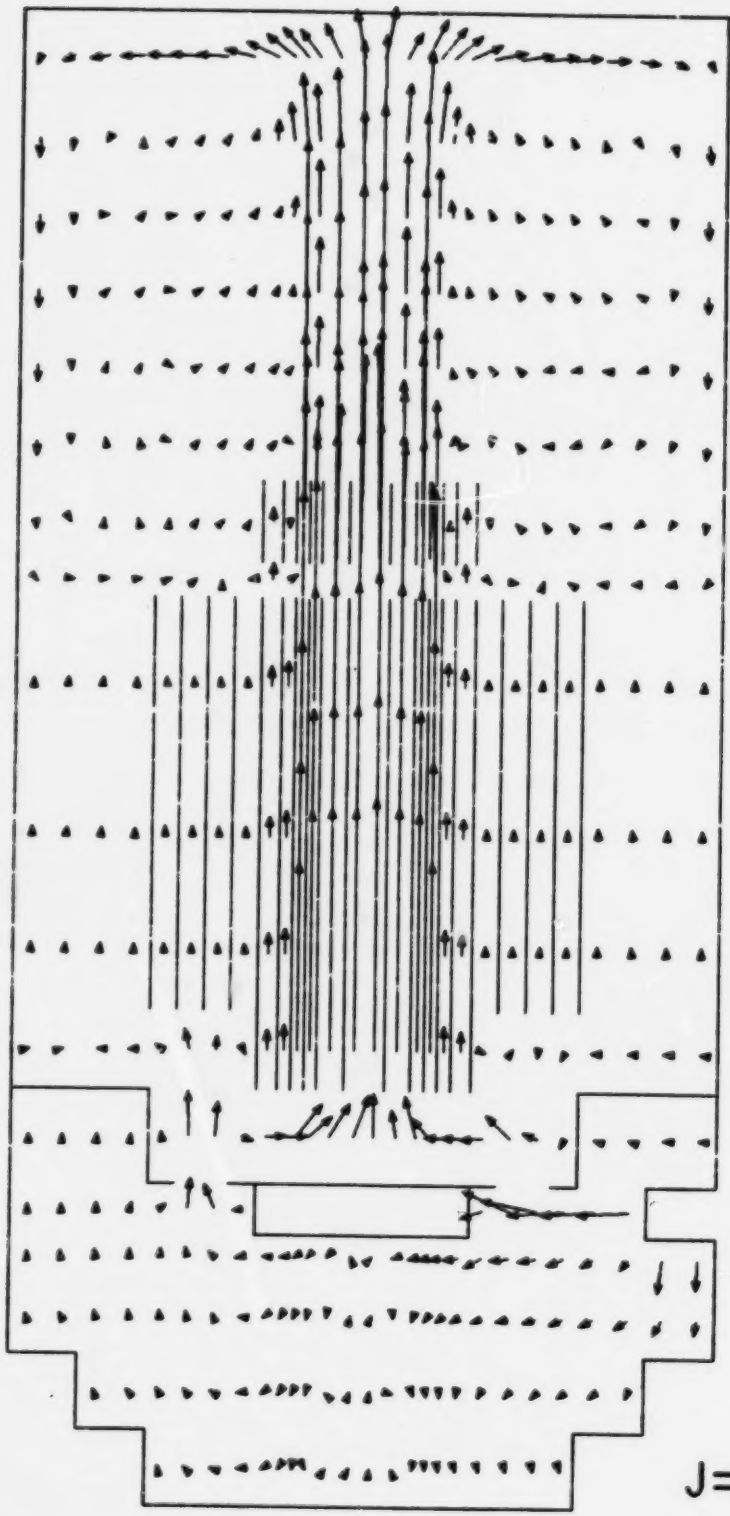

Fig. 5 (k) Velocity Vectors in R-Z Plane

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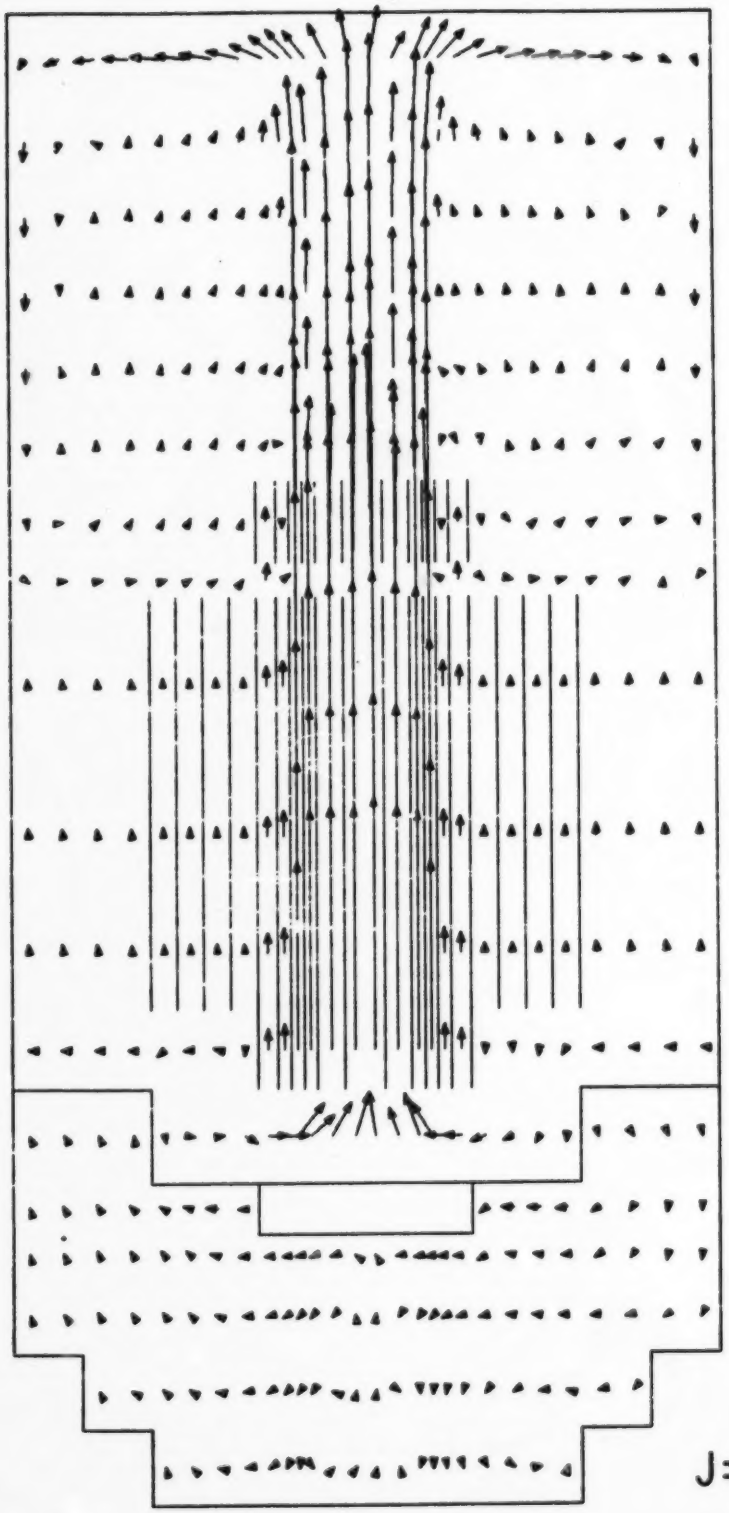

Fig. 5(ℓ) Velocity Vectors in R-Z Plane

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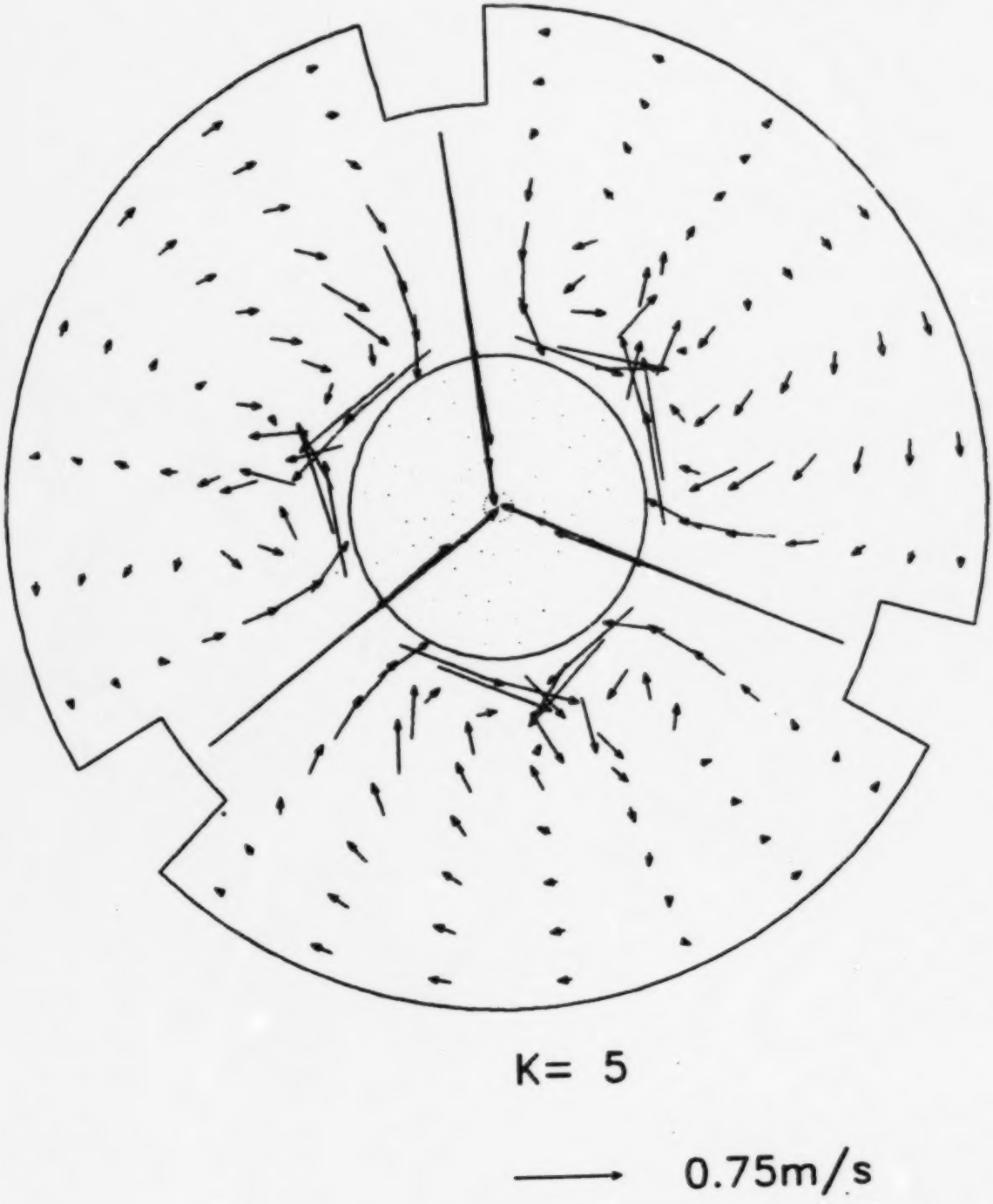

Fig. 6(a) Velocity Vectors in R-θ Plane

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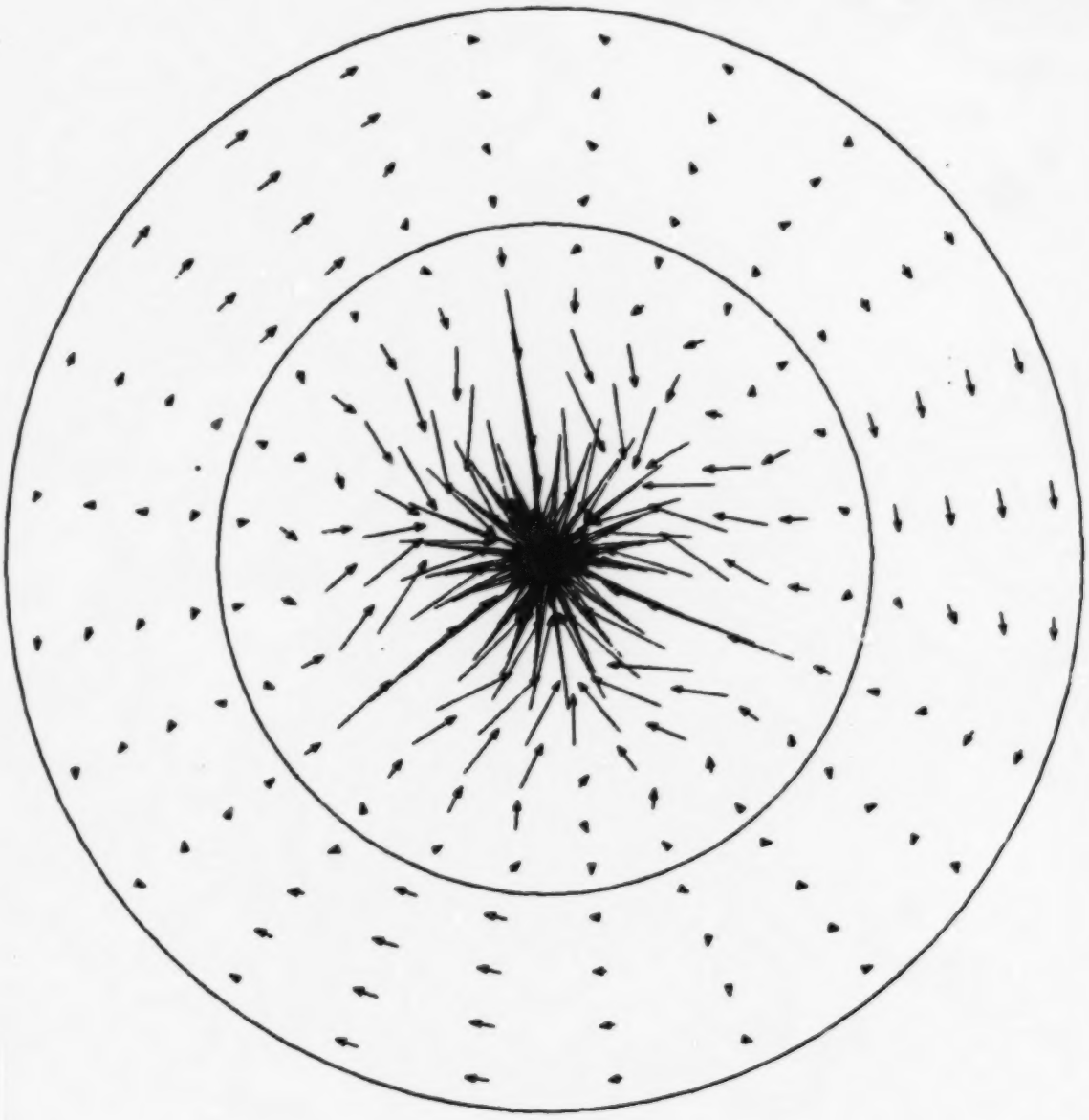

Fig. 6(b) Velocity Vectors in R-θ Plane

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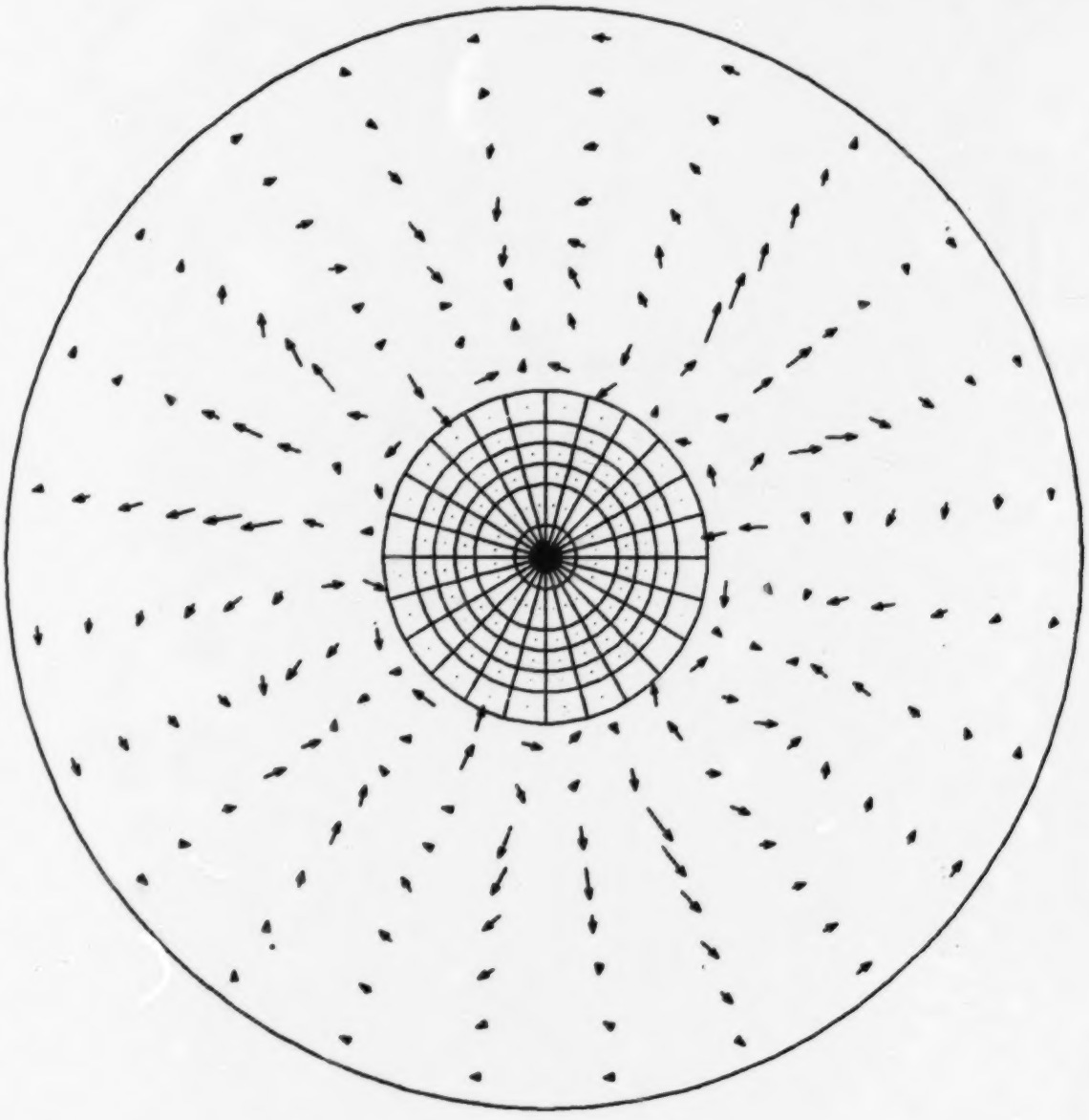

Fig. 6(c) Velocity Vectors in R-θ Plane

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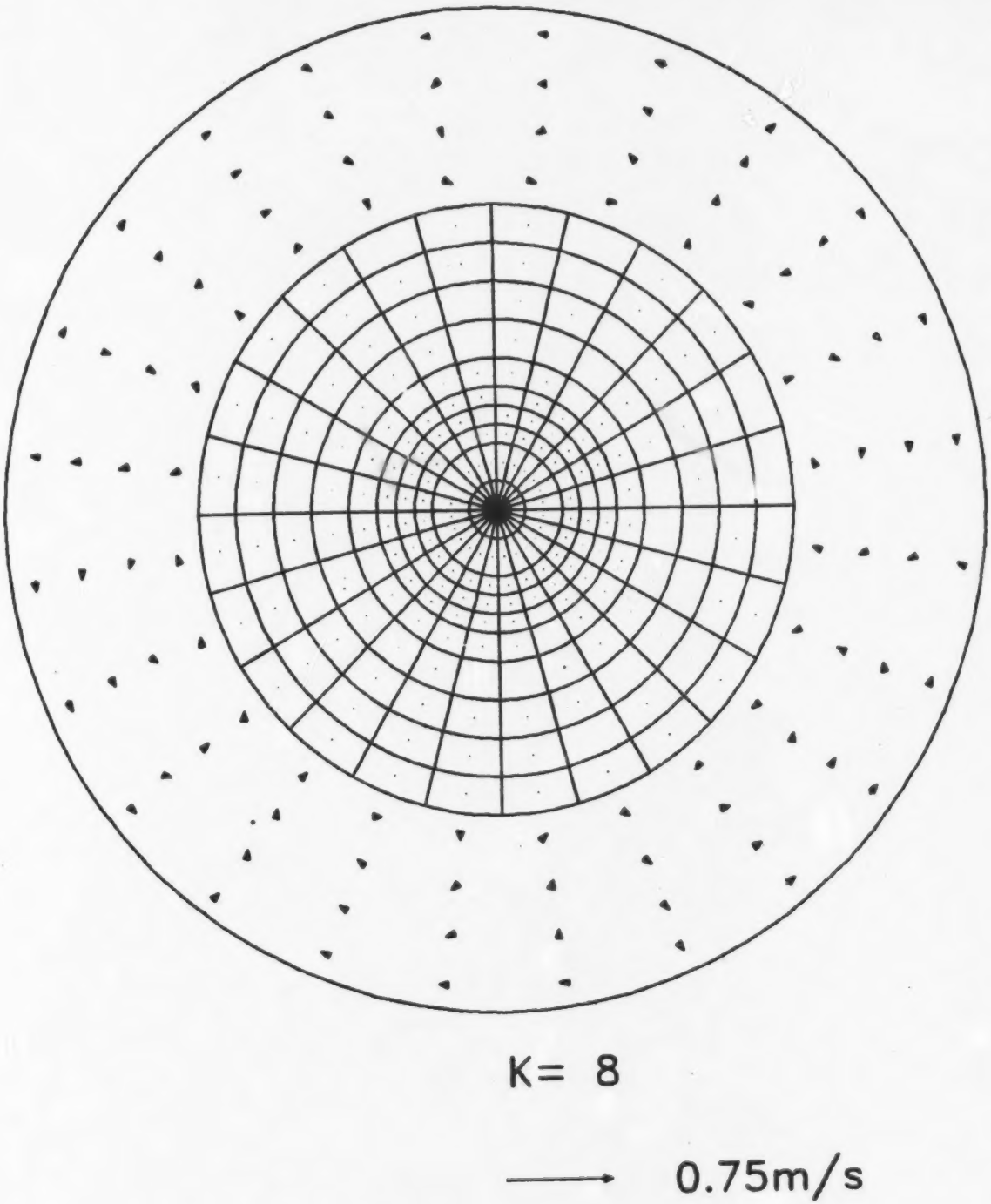

Fig. 6(d) Velocity Vectors in R-θ Plane

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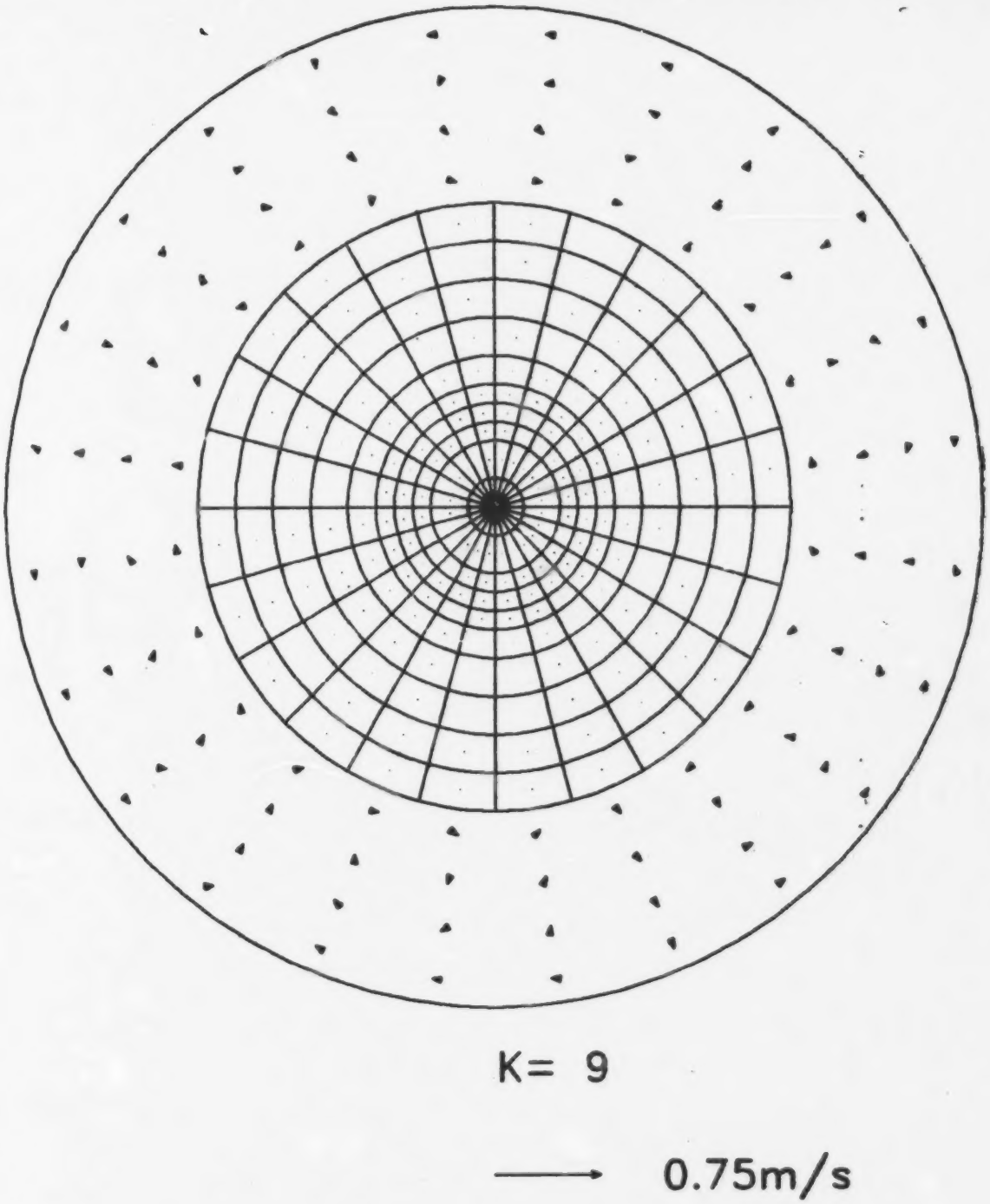

Fig. 6(e) Velocity Vectors in R-θ Plane

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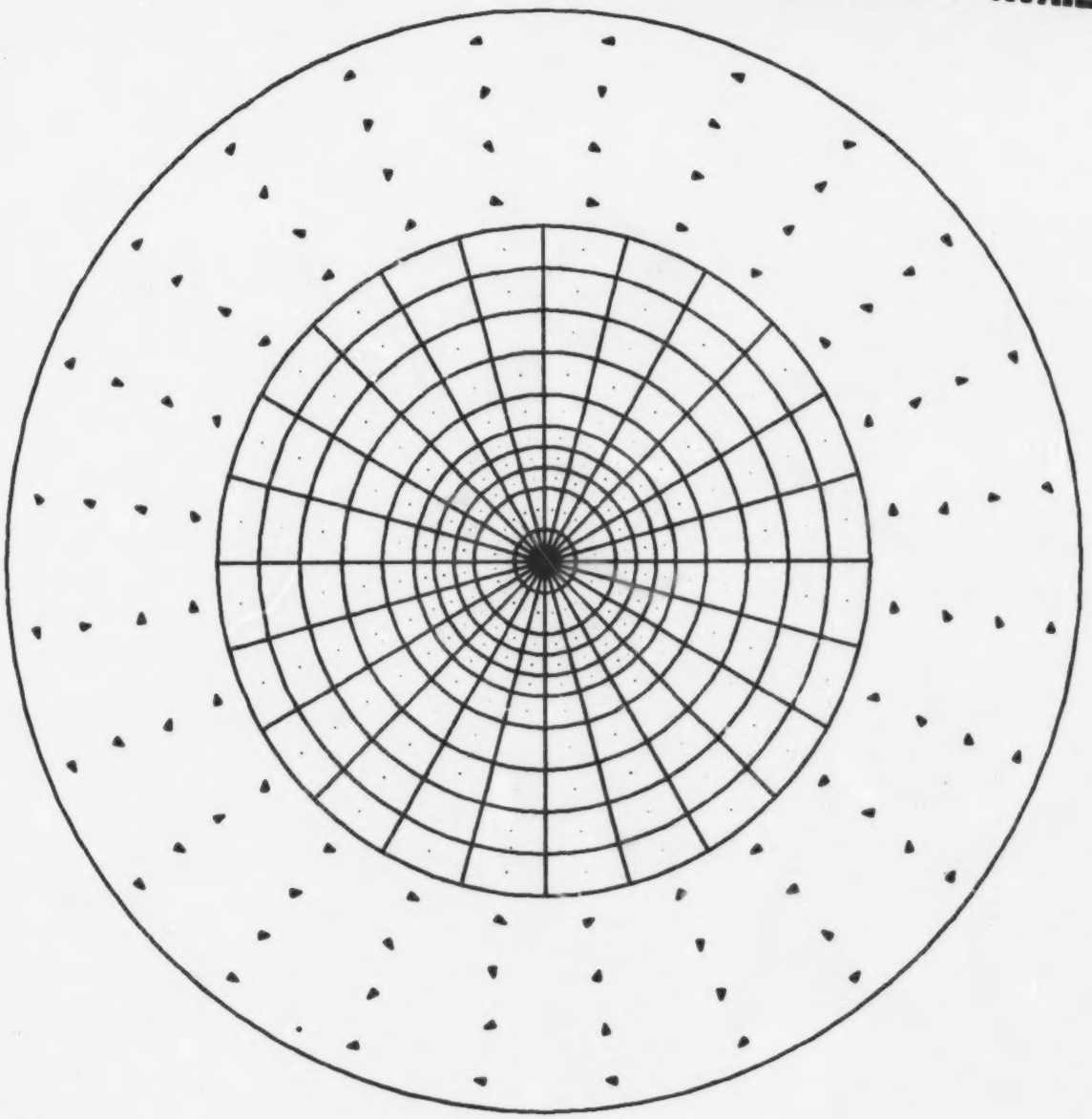

Fig. 6(f) Velocity Vectors in R-θ Plane

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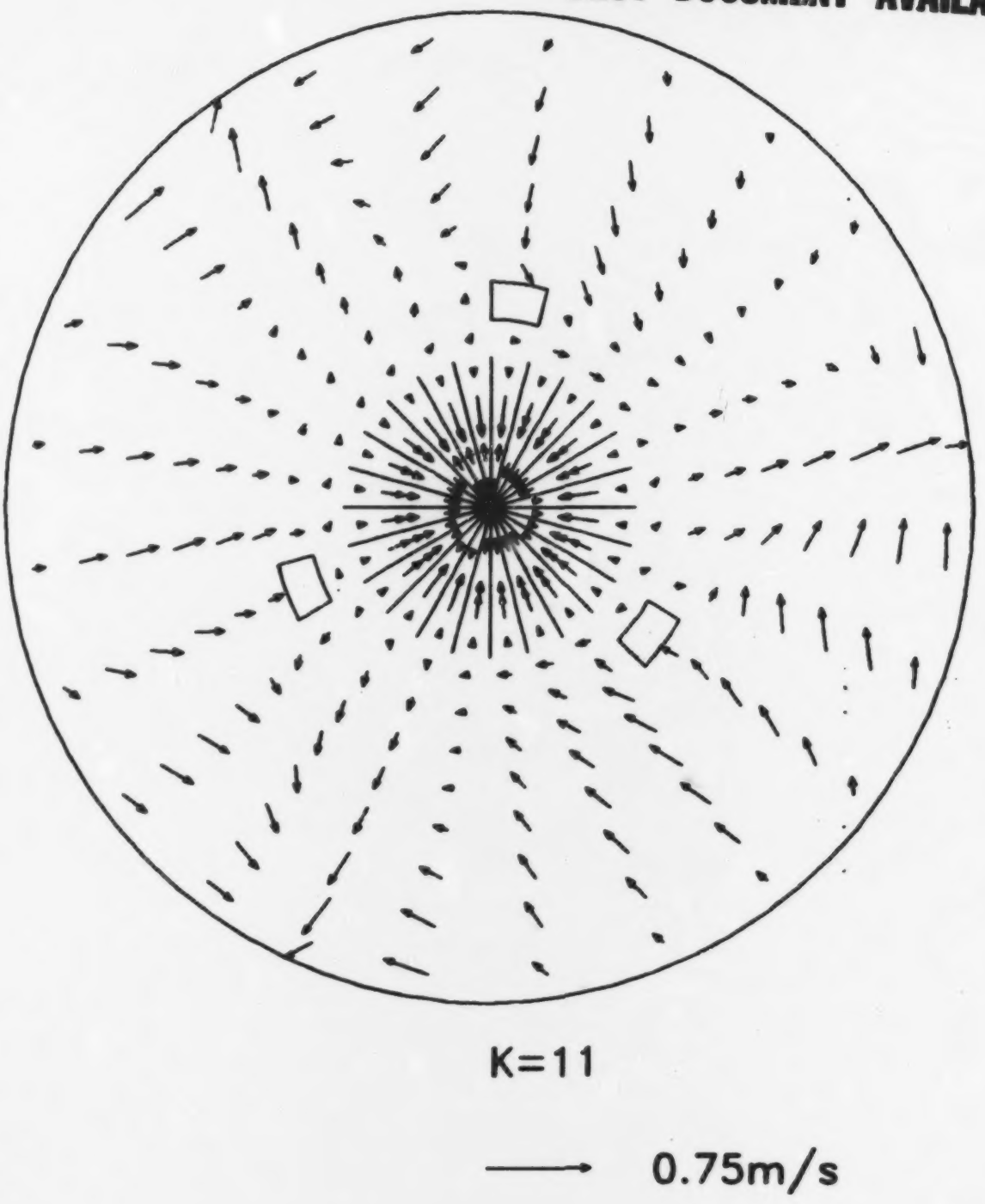

Fig. 6(8) Velocity Vectors in R-θ Plane

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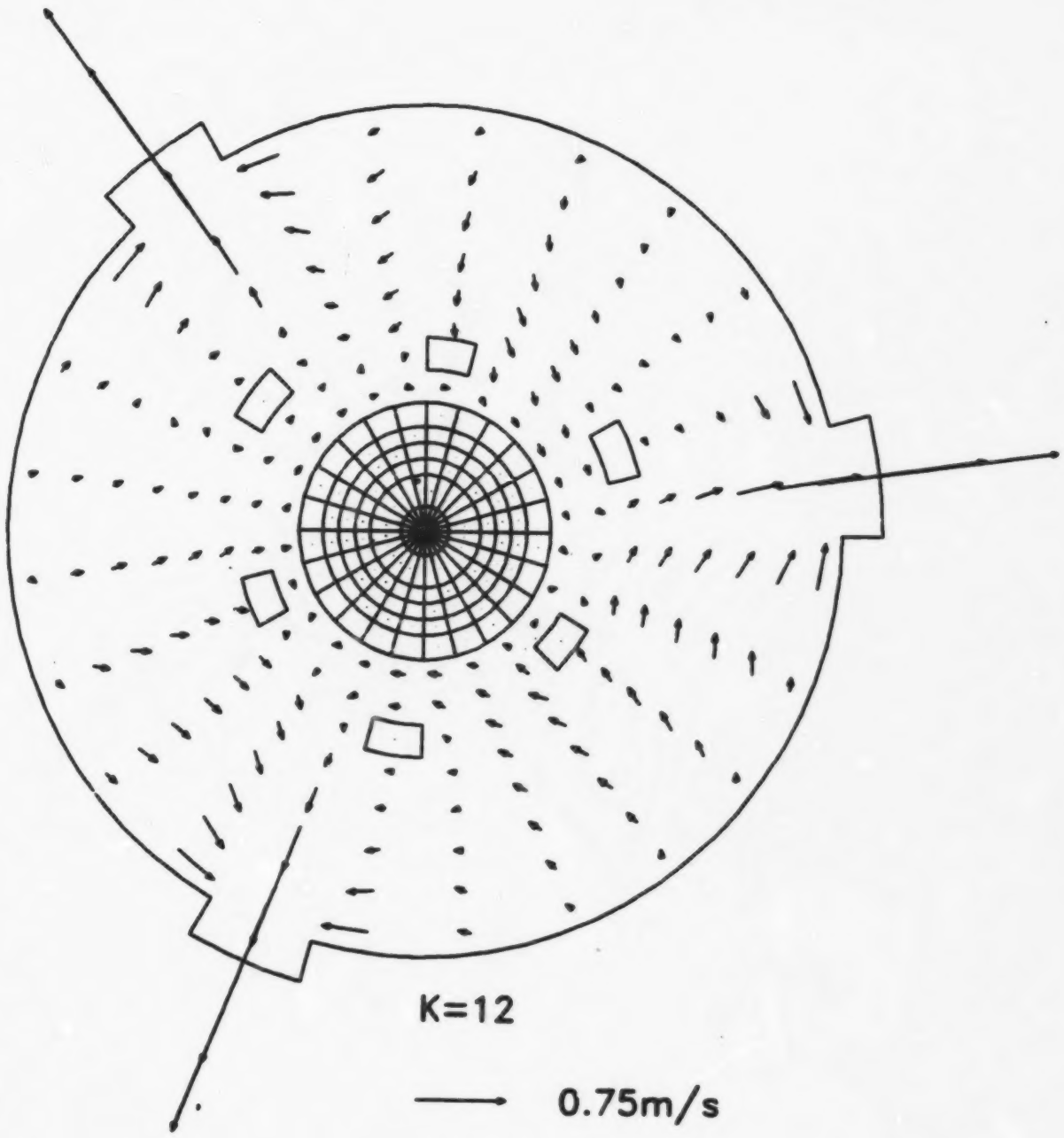

Fig. 6(h) Velocity Vectors in R-O Plane

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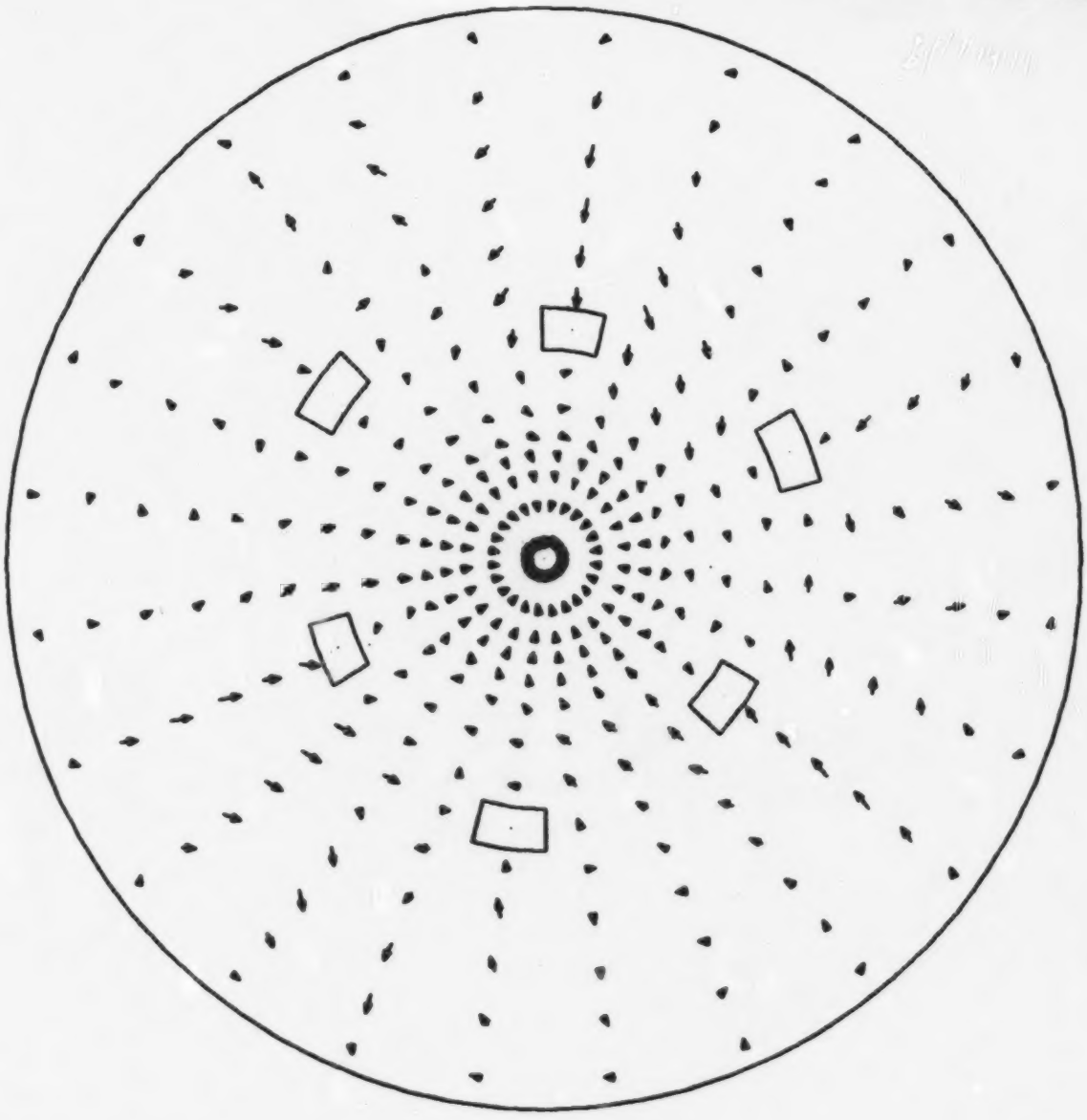

Fig. 6(i) Velocity Vectors in R-θ Plane

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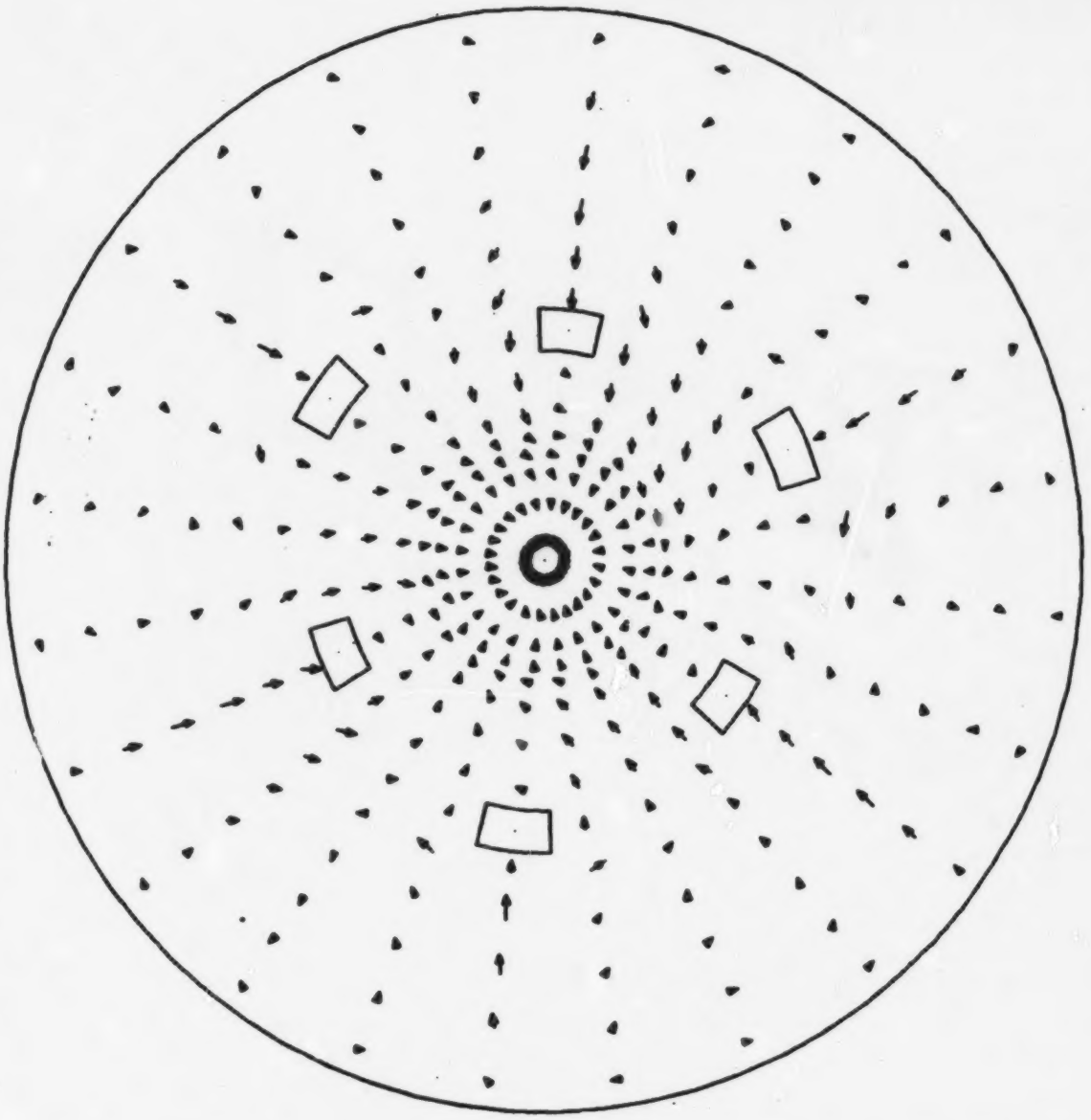

Fig. 6(j) Velocity Vectors in R-θ Plane

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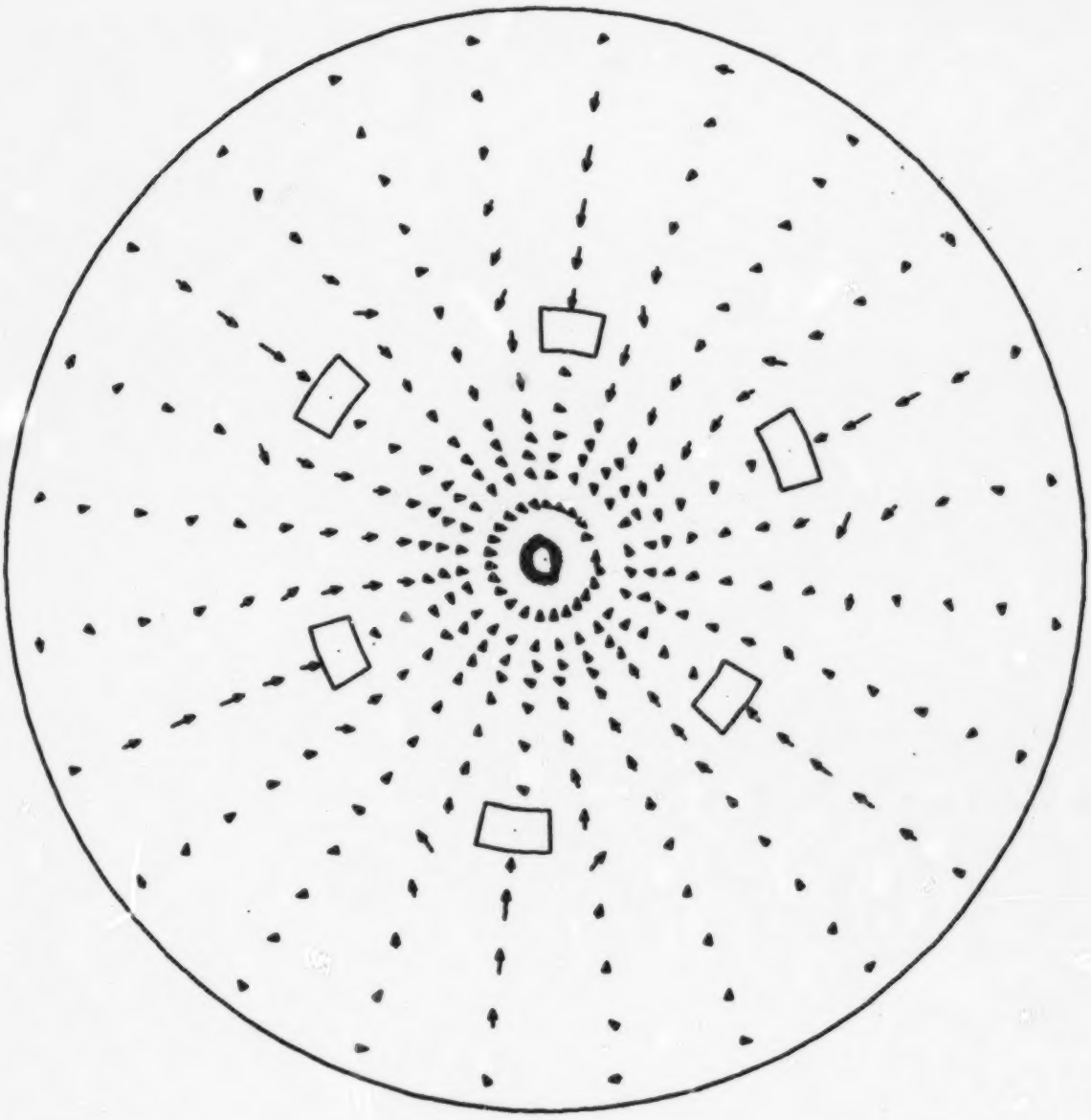

Fig. 6(k) Velocity Vectors in R-θ Plane

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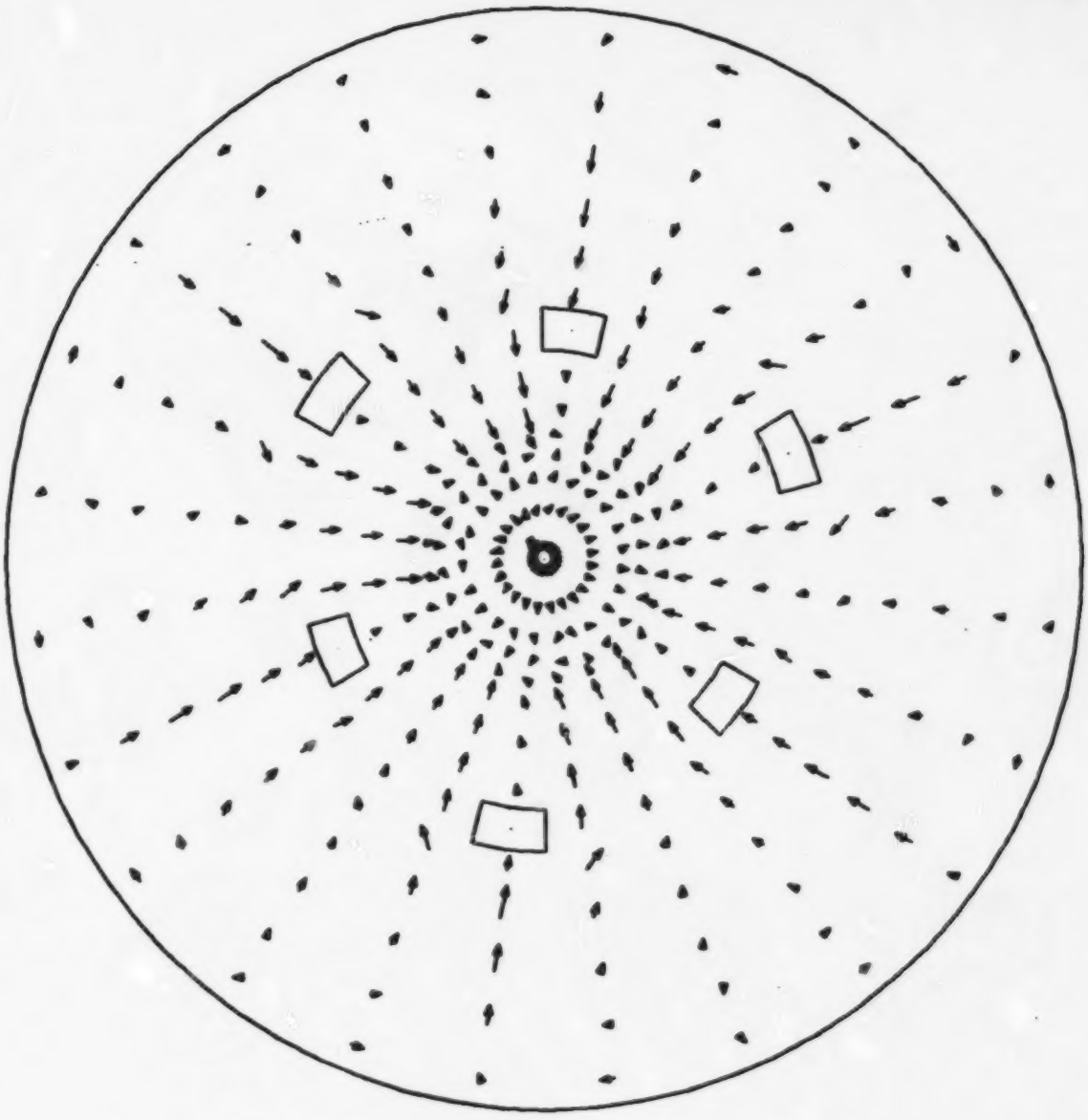

Fig. 6(1) Velocity Vectors in R-θ Plane

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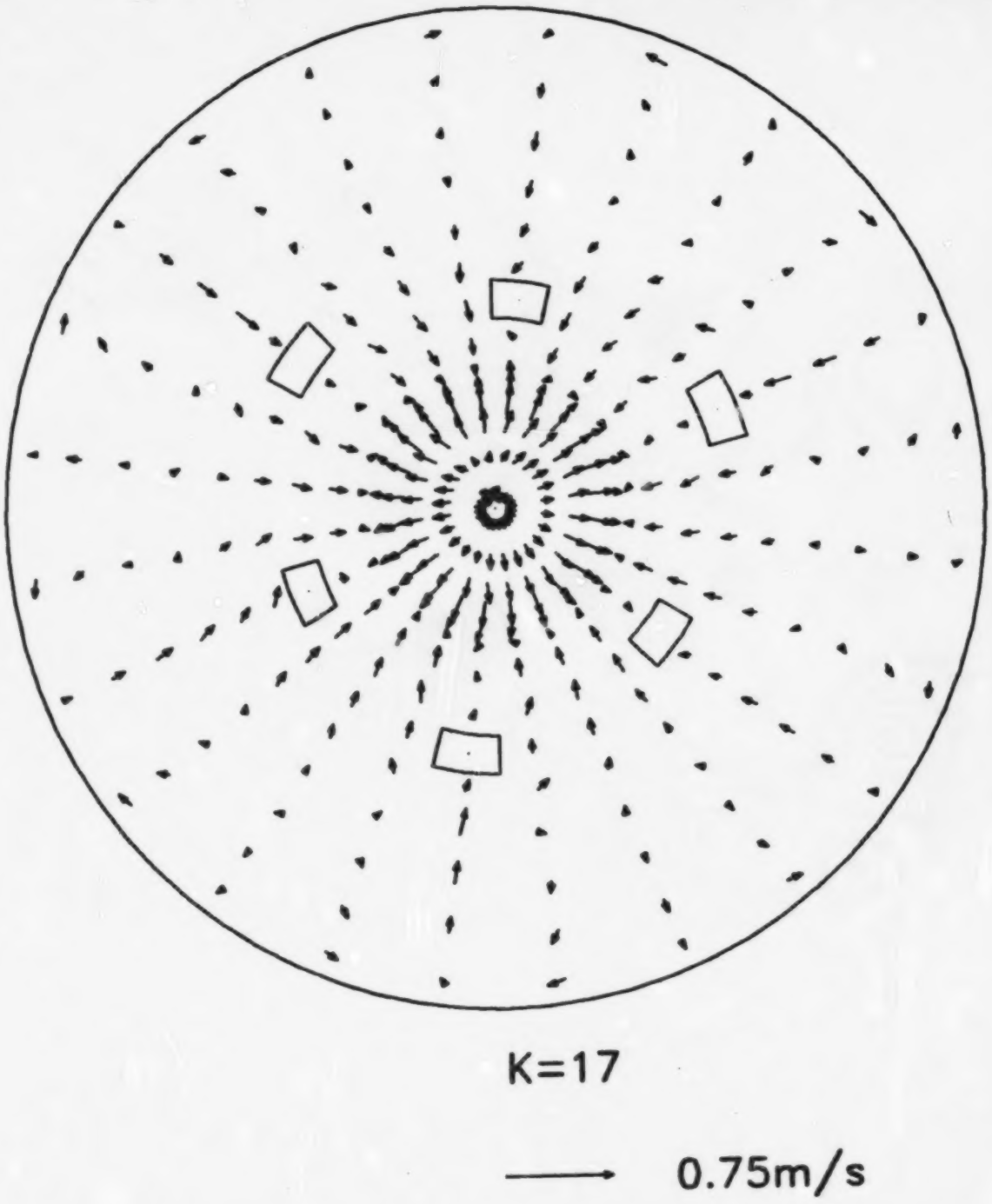

Fig. 6(m) Velocity Vectors in R-θ Plane

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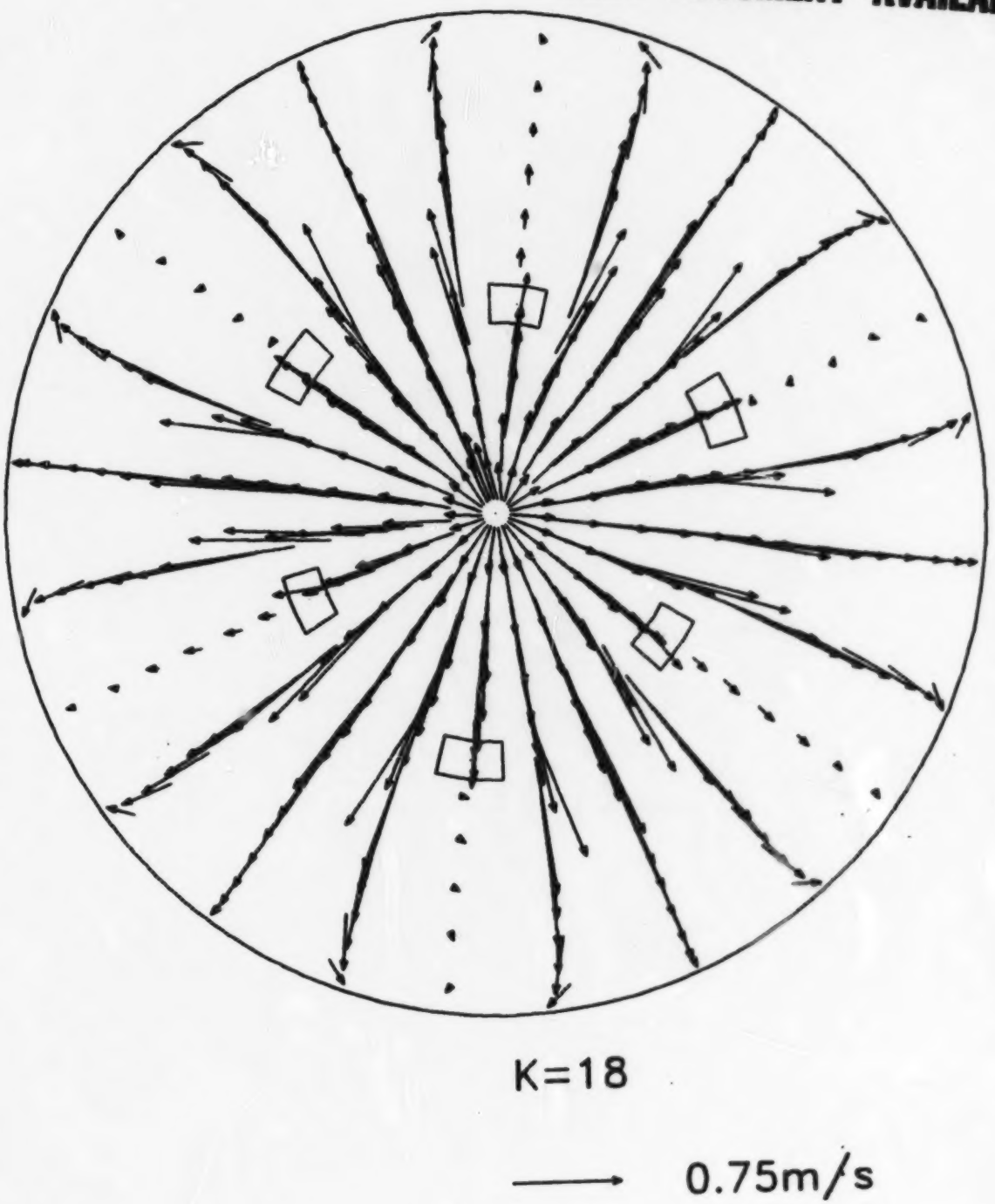

Fig. 6(n) Velocity Vectors in R-θ Plane

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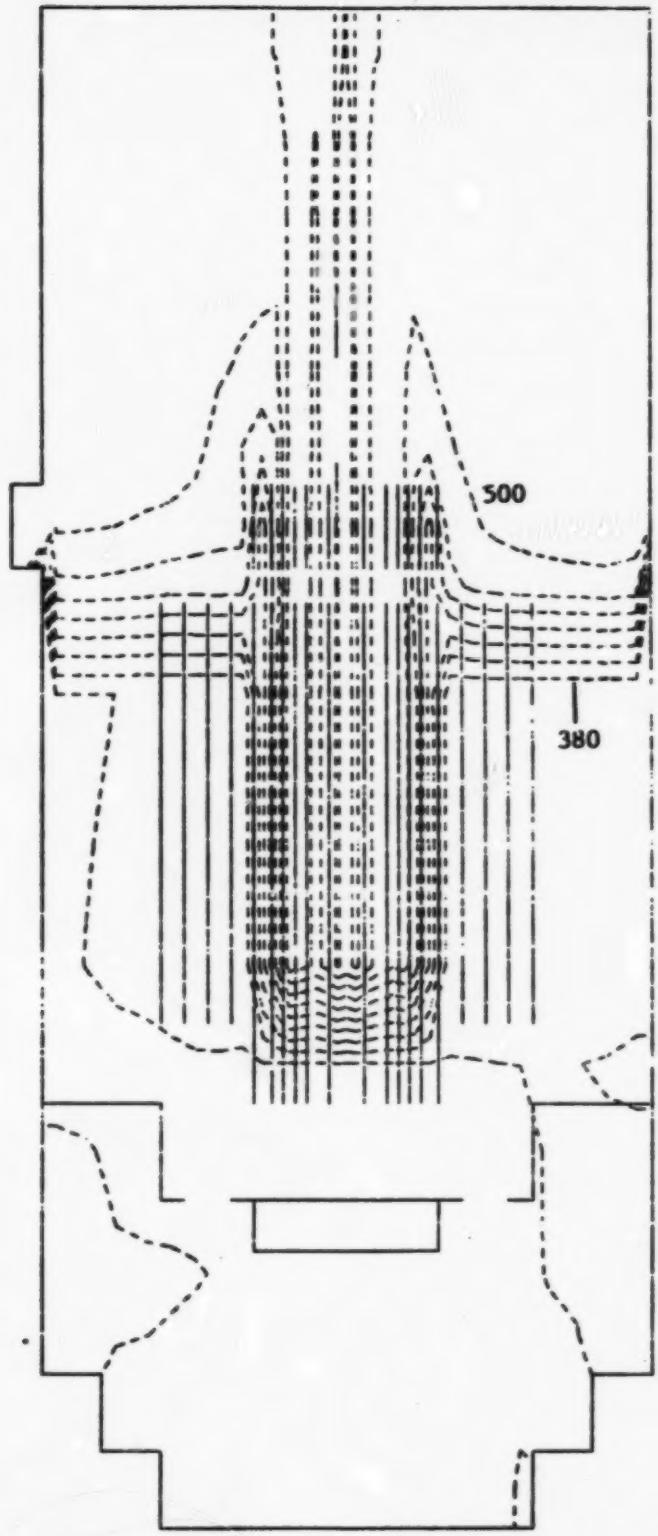

Fig. 7(a) Temperature Isotherms for Planes J = 1 (left) and J = 13 (right) (T_{min} = 360°C, T_{max} = 540°C, ΔT = 20°C)

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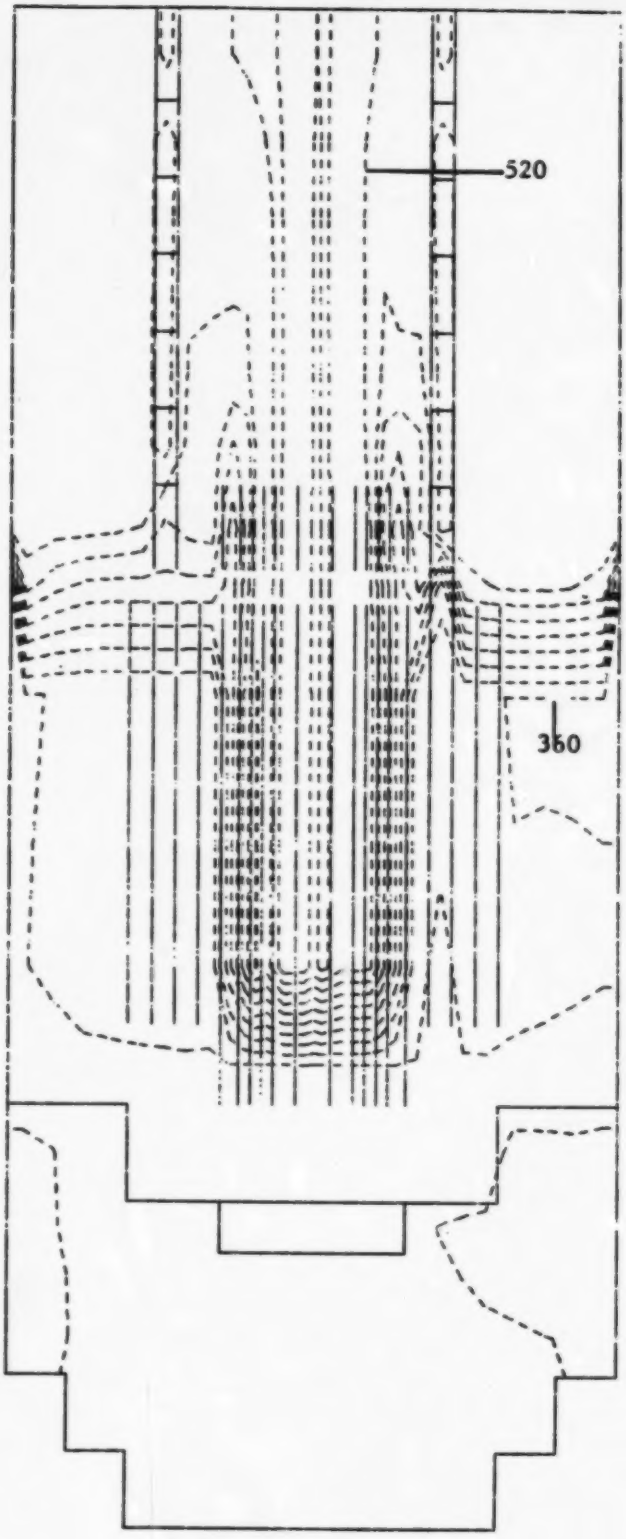

Fig. 7(b) Temperature Isotherms for Planes J = 2 (left) and J = 14 (right)

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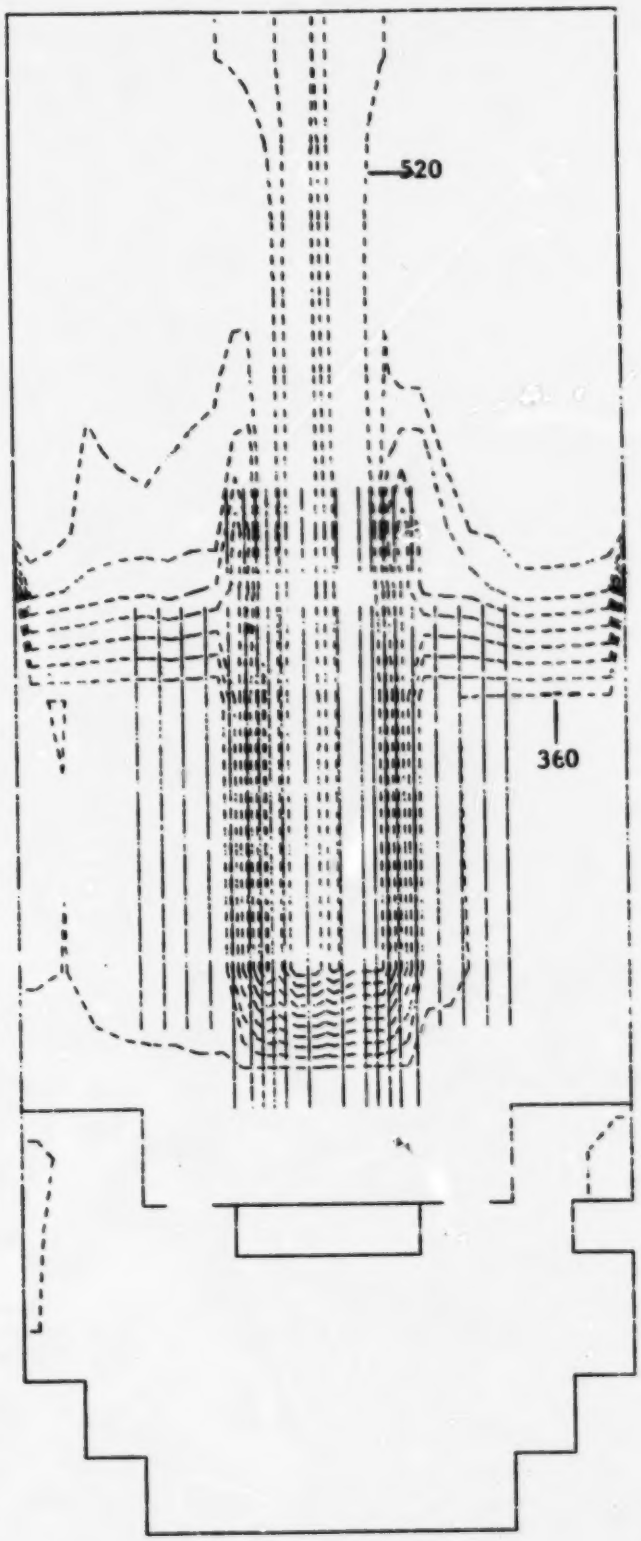

Fig. 7(c) Temperature Isotherms for Planes J = 3 (left) and J = 15 (right)

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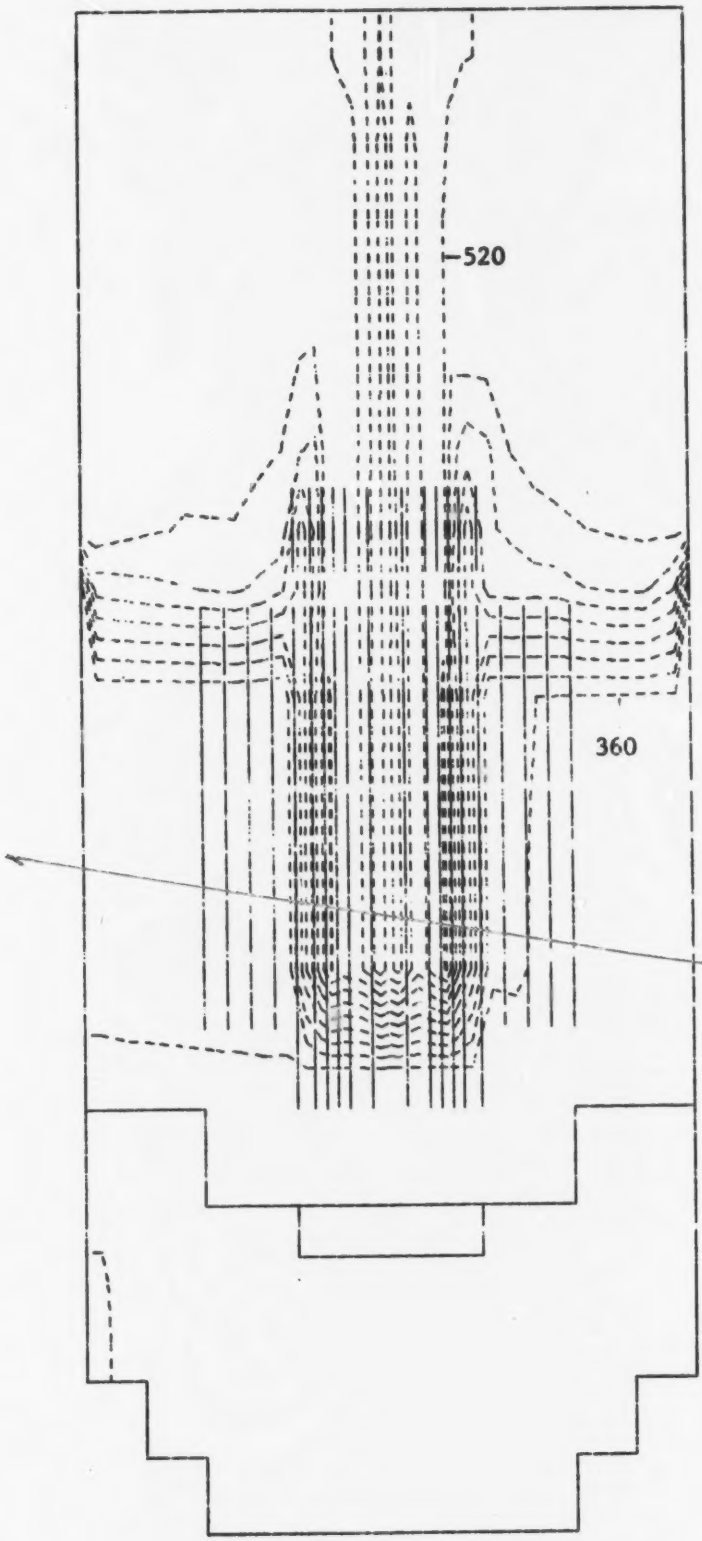

Fig. 7(d) Temperature Isotherms for Planes J = 4 (left) and J = 16 (right)

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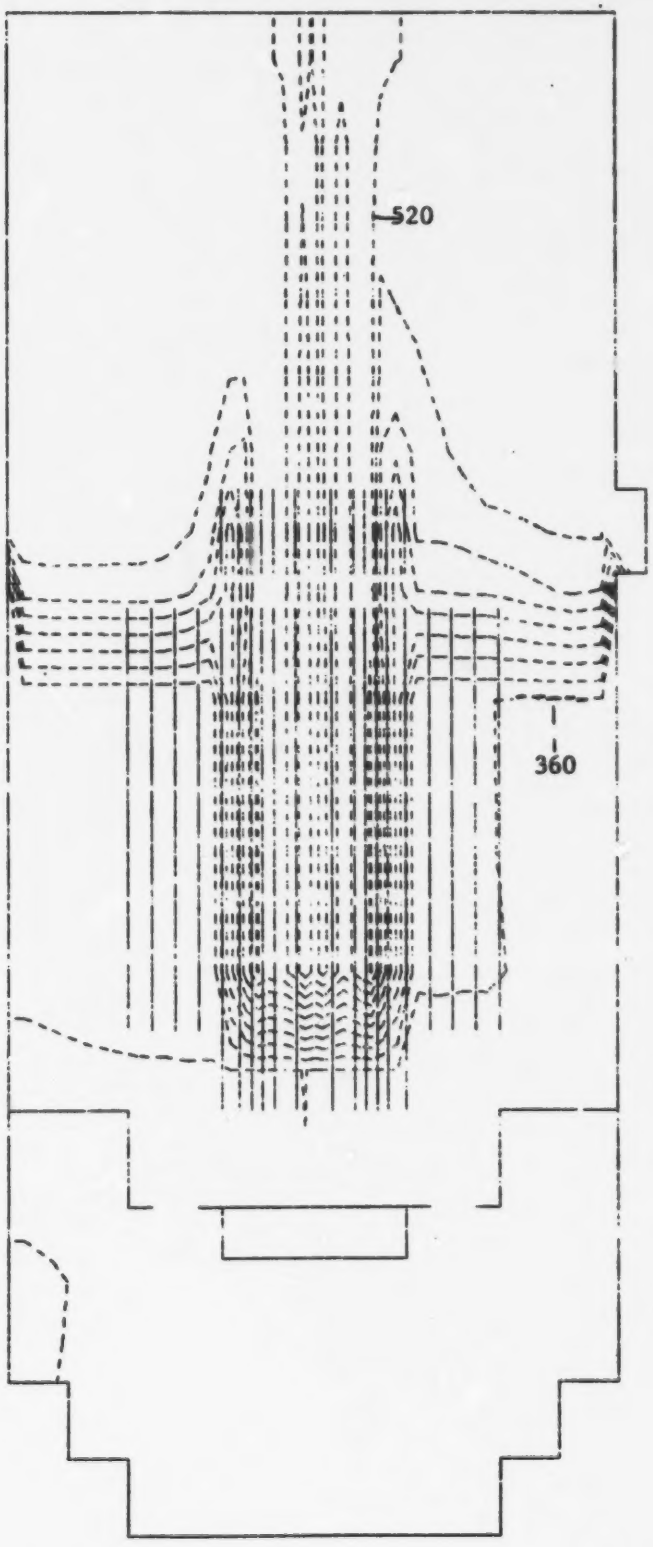

Fig. 7(e) Temperature Isotherms for Planes J = 5 (left) and J = 17 (right)

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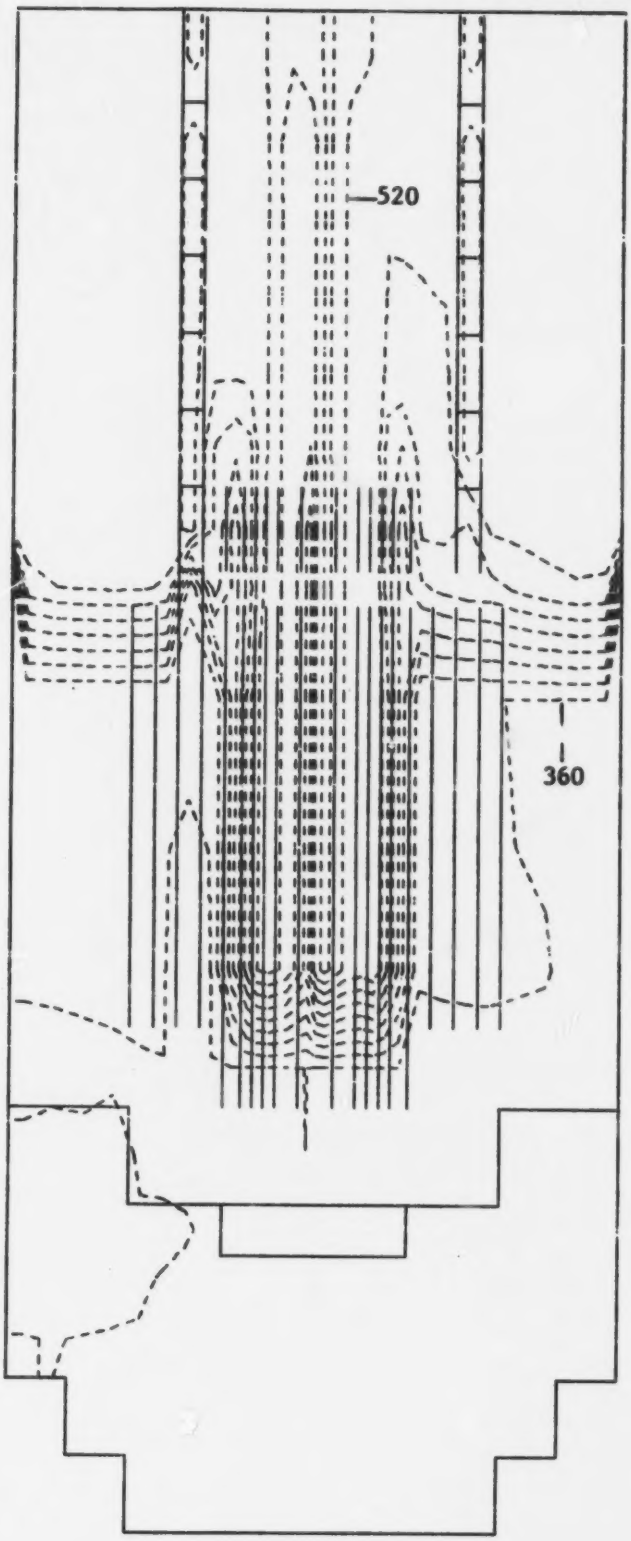

Fig. 7(f) Temperature Isotherms for Planes J = 6 (left) and J = 18 (right)

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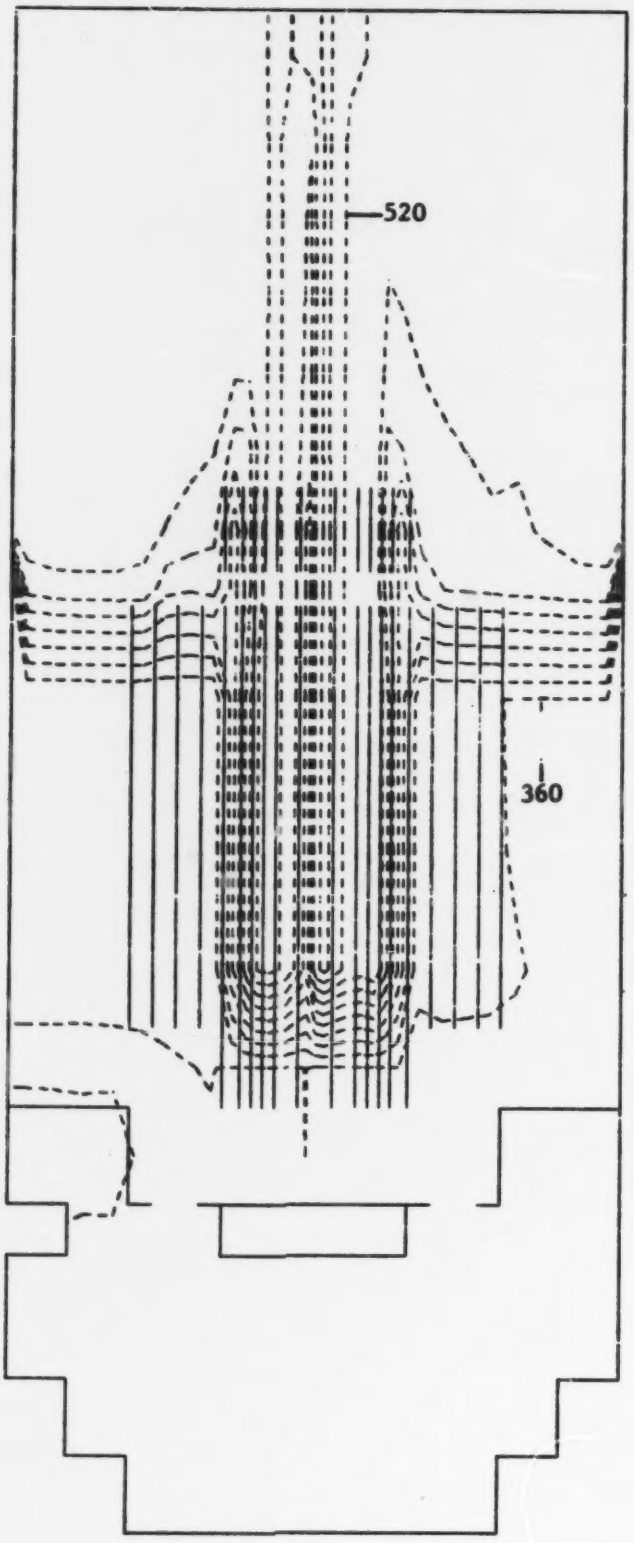

Fig. 7(g) Temperature Isotherms for Planes J = 7 (left) and J = 19 (right)

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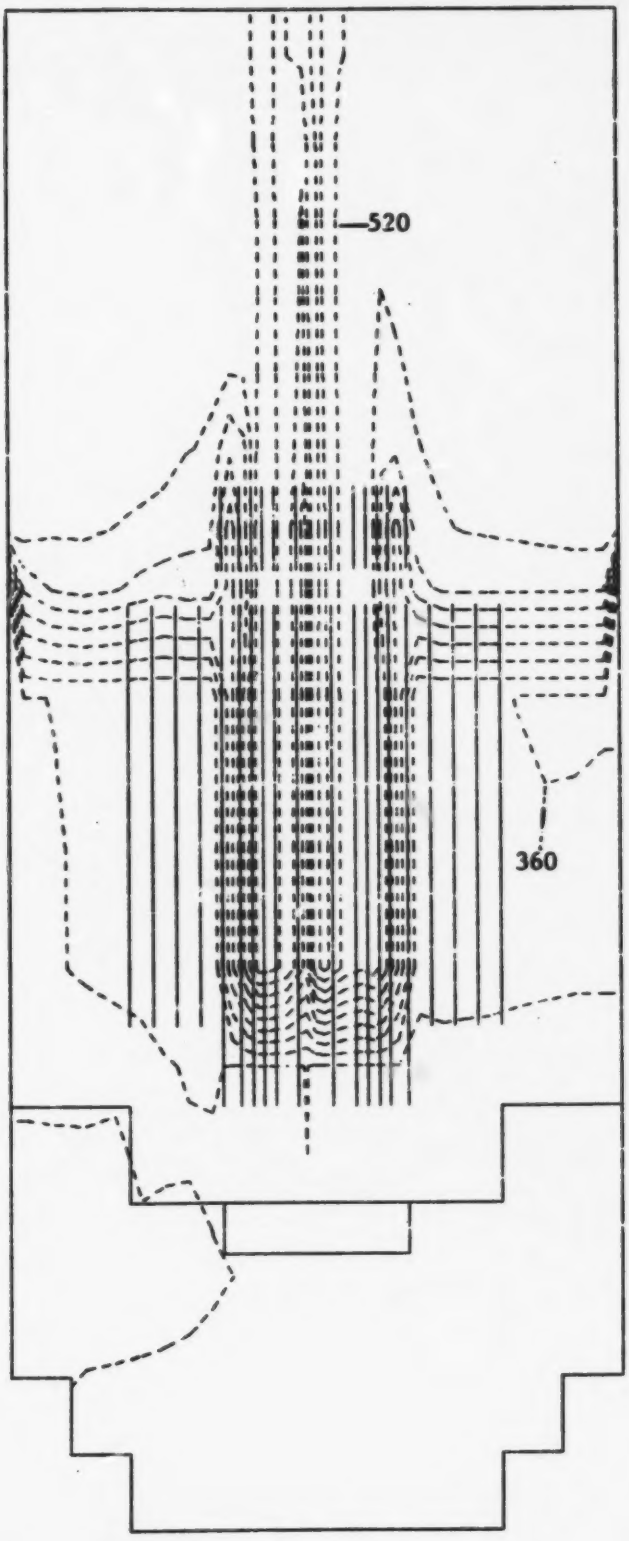

Fig. 7(h) Temperature Isotherms for Planes J = 8 (left) and J = 20 (right)

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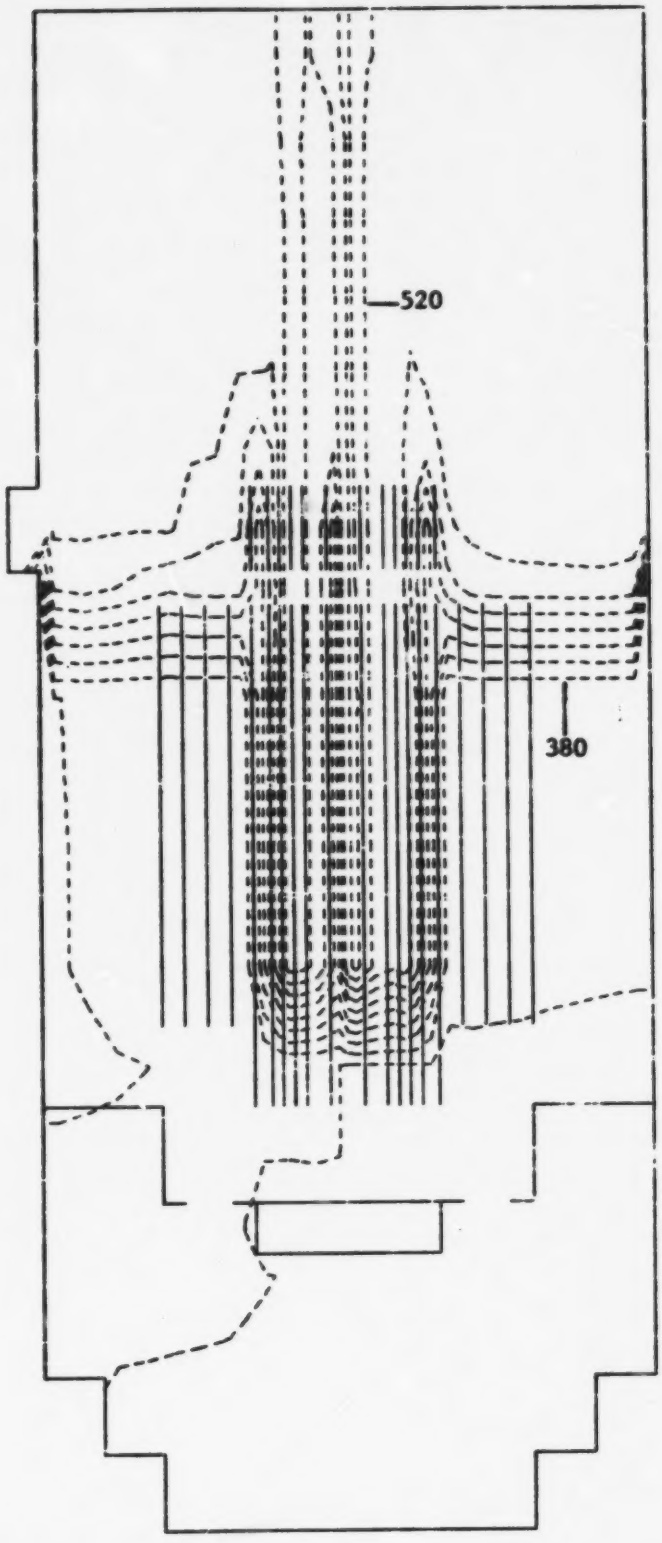

Fig. 7(i) Temperature Isotherms for Planes J = 9 (left) and J = 21 (right)

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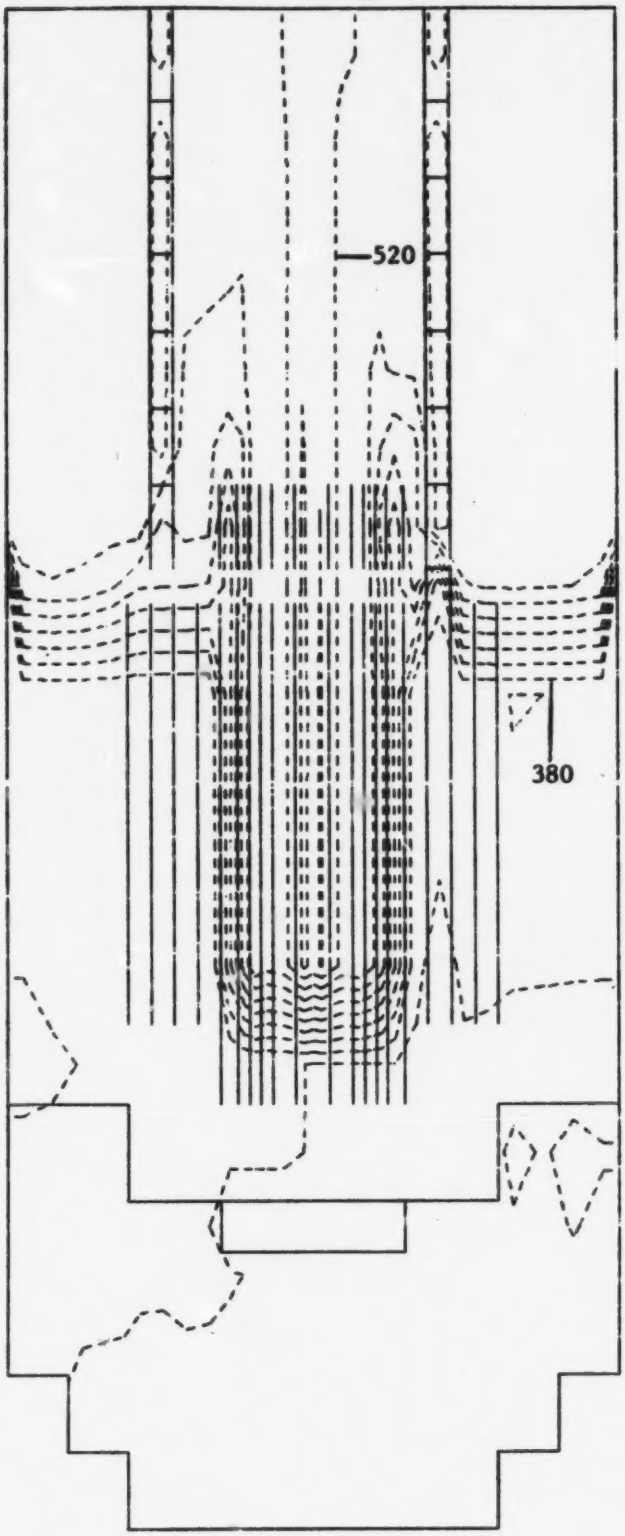

Fig. 7(j) Temperature Isotherms for Planes J = 10 (left) and J = 22 (right)

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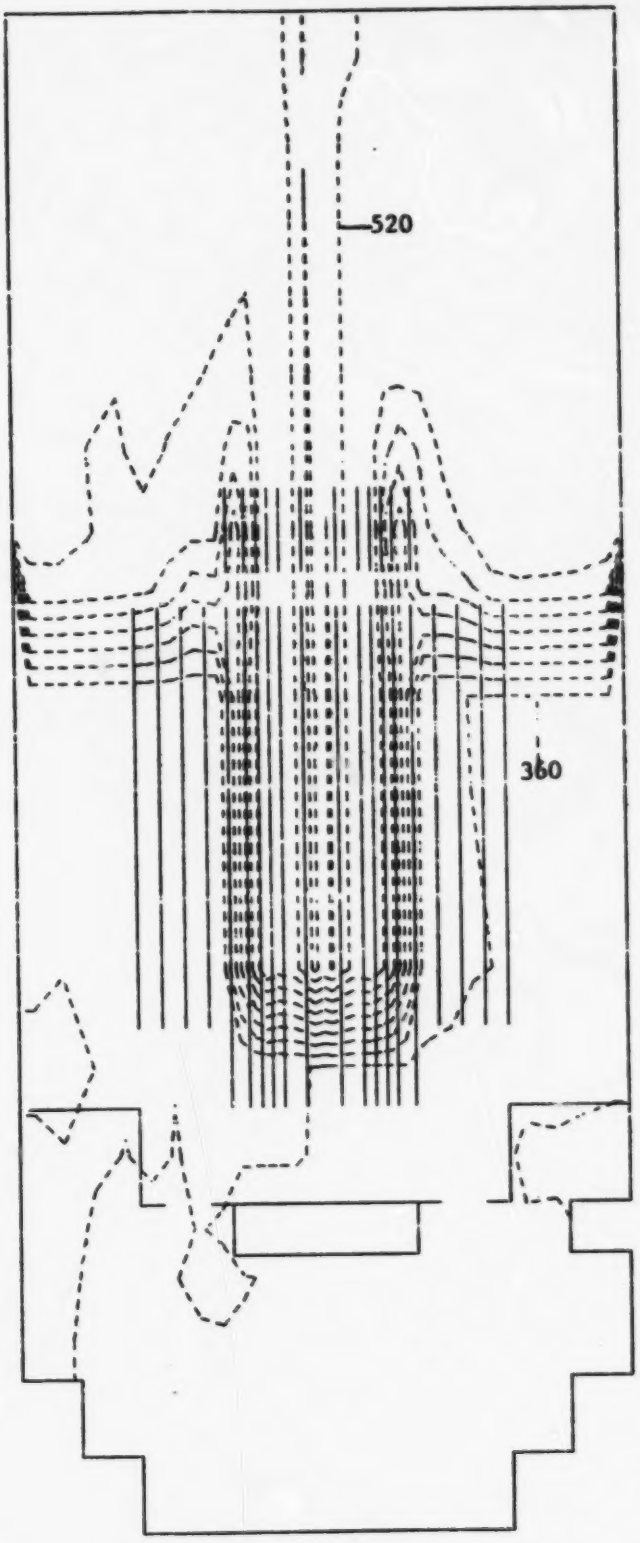

Fig. 7(k) Temperature Isotherms for Planes J = 11 (left) and J = 23 (right)

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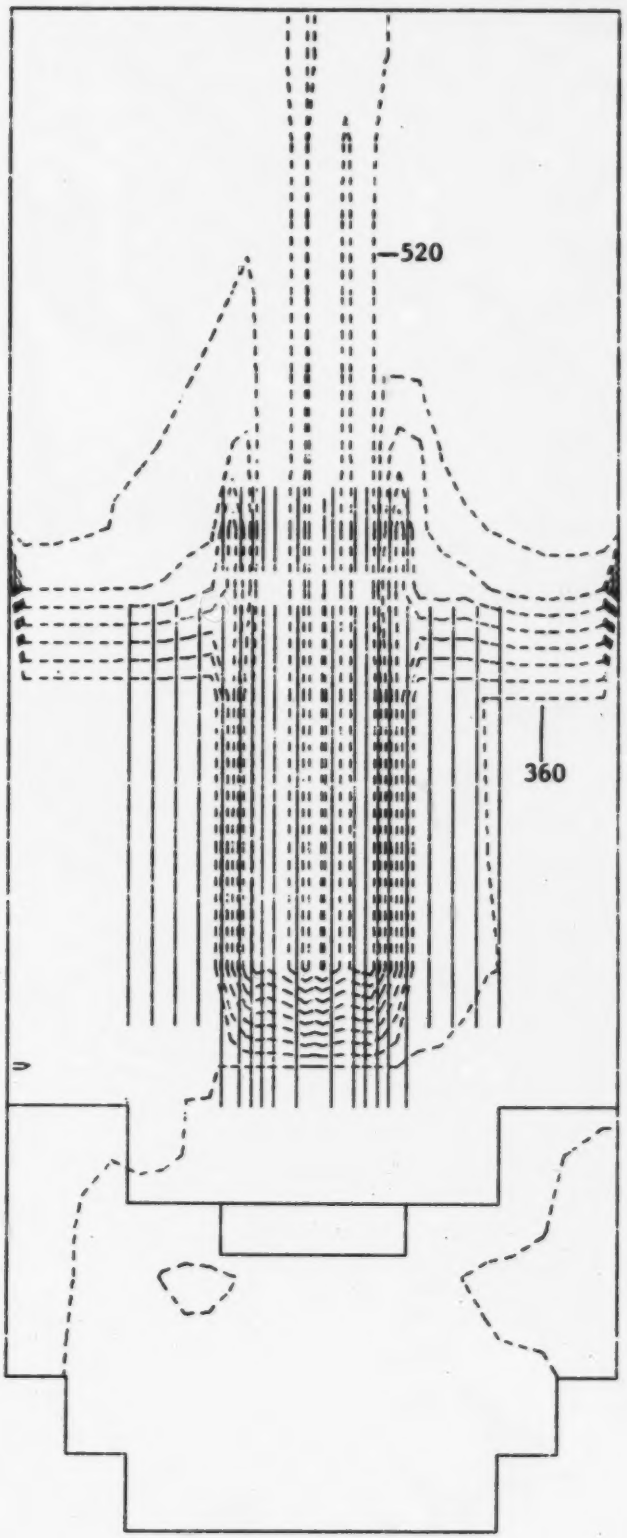

Fig. 7(ℓ) Temperature Isotherms for Planes J = 12 (left) and J = 24 (right)

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//GO.FT05F001 DD *
 &GEOM
 IGEOM=-1,LMFRNT=0,IFRES=1,
 IMAX=15,JMAX=24,KMAX=18,NSURF=17,
  DX=0.167,0.217,0.109,0.109,0.109,0.166,4*0.222,4*0.285,0.285,
 DY = 24*0.2618,
 DZ=0.6096,0.6096,0.6096,0.6096,0.3356,0.4064,0.762,0.635,0.9144,0.9646,1.4482,0.2794,
    0.6604,5*0.6096,0.7366,
 XNORML=0,-1,0,1,-1,0,0,0,0,-1,-1,0,0,0,0,-1,-1,
 YNORML=7*0,-1,1,4*0,1,-1,0,0,
 ZNORML=1,0,-1,0,0,-1,1,4*0,-1,1,0,0,0,0,0,
 &END
REG     -1.0     1  10   1  24   1   1   1   BOTTOM HALL
REG     -1.0    11  12   1  24   2   2   1   BOTTOM HALL
REG     -1.0    13  14   1  24   3   3   1
REG     -1.0    10  10   1  24   1   1   2   CORE STRC
REG     -1.0    12  12   1  24   2   2   2   CORE SUPPORT STRUC
REG     -1.0    14  14   1  24   3   4   2
REG     -1.0    14  14   1  24   6  10   2
REG     -1.0    14  14   1  24  13  18   2
REG     -1.0     1  14   1  24  18  18   3   TOP HALL
REG     -1.0     1   1   1  24   1  18   4   ORGN
REG     0.1297  12  12   7   7   5   5   5   INLET 1
REG     0.1297  12  12  15  15   5   5   5   INLET 2
REG     0.1297  12  12  23  23   5   5   5   INLET 3
REG     0.0648  13  14   7   7   4   4   6   INLET HOR SIDE
REG     0.0648  13  14  15  15   4   4   6   INLET HOR SIDE
REG     0.0648  13  14  23  23   4   4   6   INLET HOR SIDE
REG     -1.0    13  14   7   7   6   6   7   INLET HOR SIDE
REG     -1.0    13  14  15  15   6   6   7   INLET HOR FACE
REG     -1.0    13  14  23  23   6   6   7   INLT HOR FACE
REG     -1.0    13  14   6   6   5   5   8   INLT TANGENT FACE
REG     -1.0    13  14  14  14   5   5   8
REG     -1.0    13  14  22  22   5   5   8
REG     -1.0    13  14   8   8   5   5   9   INLT TANGENT FACE
REG     -1.0    13  14  16  16   5   5   9   INLT TANGENT FACE
REG     -1.0    13  14  24  24   5   5   9
REG     -1.0    14  14   1   6   5   5  10   CORE STRUCTURE
REG     -1.0    14  14   8  14   5   5  10       AT
REG     -1.0    14  14  16  22   5   5  10   INLET
REG     -1.0    14  14  24  24   5   5  10
REG     0.3972  15  15   1   1  12  12  11   OUTLET
PEG     0.3972  15  15   9   9  12  12  11
REG     0.3972  15  15  17  17  12  12  11   OUTLET
REG     -1.0    15  15   1   1  12  12  12   OUTLT
PEG     -1.0    15  15   9   9  12  12  12
```


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```
REG     -1.0    15  15  17  17  12  12  12   HOR FACE
REG     -1.0    15  15   1   1  12  12  13   OUTLT HOR FACE
REG     -1.0    15  15   9   9  12  12  13
REG     -1.0    15  15  17  17  12  12  13
REG     -1.0    15  15   1   1  12  12  14   OUTLET TANGENT FACE
REG     -1.0    15  15   9   9  12  12  14   OUTLET TANGENT FACE
REG     -1.0    15  15  17  17  12  12  14
REG     -1.0    15  15   1   1  12  12  15
REG     -1.0    15  15   9   9  12  12  15
REG     -1.0    15  15  17  17  12  12  15
REG     -1.0    14  14   2   8  12  12  16
REG     -1.0    14  14  10  16  12  12  16
REG     -1.0    14  14  18  24  12  12  16
REG     -1.0    14  14   1  24  11  11  17      SIDE INLET
END
 &DATA
  IBOIL  =  0 , IDOOP = 0, IDRAG=0,IDTIME=1,
 IFENER=3,IFITEN=0,IFPROP=0,
 IFREB=1, IFROD=0,IFUEL=0,INIT=0,
  ISTATE=0,ISTRUC=1,ISWEEP=0,
 ISYNCH=2, ITIBUG=0,ITIMER=0,
 ITURKE=0, IXZBUG=0,
 IXREB=0, IYREB=0, IZREB=0,
 IENDUG=0,
 HYDALL=2.911,HYDIN=2.911, HYDOUT=2.911,
 CNU1  = 0.0, CEL1=0.0,
 CDRAGX = 1.0 , CDRAGY=1.0, CDRAGZ=1.0,
 AO = 0.5 , BO=0.0,
 TREST=50.0, TSTART=0.0,
 VELOC=2*0.0,0.00337,0.0,2*3.043,4*0.0,2.040,4*0.0,0.0,0.0,0.01765,
 KFLOW=3*1,-3,6*1,-5,6*1,
 TEMP = 17*360.0,
 KTEMP=2*400,1,400,1,1,10*400,1,
 PRES=17*0.0,
 KPRES=17*0,DPDX=0.0,DPDY=0.0,DPDZ=0.0,
 EPS1=0.0001,EPS2=1.0E-06,EPS3=1.0E-5,
 NTHCON(1)=-1,
  ROTIME=0.85,
  IT=50,
  NTMAX=2,TIMAX=3.6E7,
 PRES0 = 1.0135E5,
 XPRES0=3.053 , YPRES0=1.0472, ZPRES0=8.0,
 GRAVX= 0.0 , GRAVY=0.0 , GRAVZ= -9.81,
 OMEGA = 1.5 , DLCUT= 0.5 , TEMP0= 360.0,
 TURDV = 0.0 , TURBC=0.0,
 CWIREX= 0.5 , CWIREY=0.5, CWIREZ=0.5,
 IFPLOT=-1, NTPRNT=-9999,
 ISTPR=1201,2201,3201,5201,6201,7201,8201,10201,12201,11201,
       1207,2207,3207,5207,6207,7207,8207,10207,12207,11207,
 NTHPR=1201,2201,3201,5201,6201,7201,8201,10201,11201,12201,
       1027,2207,3207,5207,6207,7207,8207,10207,12207,11207,
       9201,17201,9207,17207,
 NFORCE=15,NCORR=10,
 CLENTH=12*-1.0,6.35E-3,2*1.0,
 REYLEN=6*9.347E-3,2*8.128-3,4*1.0,6.35E-3,2*1.0,
```

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```
 FORCEF=2*0.50,4*0.5,2*3.0,4*1.0,0.5,1.0,1000.0,
 FOR(5)=1.0,
 ICORR=1,2,1,3,4,5,6,7,2*8,2*9,10,2*9,
 ACORRL=1.844E6,1.5983E6,4.62E5,6144.46,5866.1,4.80E4,
        7.396E4,1.0E4,0.5,64.0,
 ACORRT=75.847,65.76,71.26,140.10,133.73,701.45,1080.4,1.0E4,0.5,
        0.3164,
 BCORRL=-1.479,-1.479,-1.259,-0.5832,-0.5832,-0.1,-0.1,2*0.0,-1.0,
 BCORRT=-.1055,-.1085,-.09954,-.1005,-.1005,-.02929,-.02929,
         2*0.0,-0.25,
 CCORRL=10*0.0,
 CCORRT=10*0.0,
 REYTRN=1585.0,1585.0,3*2228.0,2*0.0,2*1.0E10,2000.0,
 NREDRT=4,IREBIT=5,NREBH=1432,576,1008,2688,
 NREBX=0,0,0,3,NREBZ=24,336,336,0,
 NWATER=2,C0K=2.3,23.0,C1K=0.0,0.0,
 CORO=1.0,7687.0,COCP=2.85E6,577.0,
 C1CP=500.0,GK=10*1.0,
 &END
   1   1  10   1  24   1   1     REGION 1
   1   1  12   1  24   2   2
   1   1  14   1  24   3   4
   1   7  12   1  24   5   5
   1  11  14   1  24   6   6
   1  13  14   1   6   5   5
   1  13  14   8  14   5   5
   1  13  14  16  22   5   5
   1  13  14  24  24   5   5
   2   1  10   1  24   6   6     REGION 2
   2   1  14   1  24   7   7
   3   1  14   1  24   8  10     REGION 3
   4   1  14   1  24  11  18     REGION 5
   4  14  14   1   1  12  12     NREBX
   4  14  14   9   9  12  12
   4  14  14  17  17  12  12
   1   8   9   1   1   5   5     NREBZ 1
   1   8   9   3   3   5   5
   1   8   9   5   5   5   5
   1   8   9   7   7   5   5
   1   8   9   9   9   5   5
   1   8   9  11  11   5   5
   1   8   9  13  13   5   5
   1   8   9  15  15   5   5
   1   8   9  17  17   5   5
   1   8   9  19  19   5   5
   1   8   9  21  21   5   5
   1   8   9  23  23   5   5
   2   1  14   1  24   7   7     NREBZ 2
   3   1  14   1  24  10  10     NREBZ 3
FORC
ZFOR   1   1   1   2  21   7   7      CORE1
ZFOR   2   1   1  22  24   7   7
ZFOR   2   1   1   1   1   7   7      CORE1
ZFOR   3   2   2   1  24   7   7       CORE2
ZFOR   4   3   3   1  24   7   7       CORE3
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ZFOR   5   4   4   1   5   7   7      CORE4
ZFOR   5   4   4   8  24   7   7
ZFOR   6   4   4   6   7   7   7      CORE4
ZFOR   7   5   5   1  24   7   7
ZFOR   8   6   6   1  24   7   7
ZFOR   9   7  10   1  24   7   7
ZFOR  10  11  14   1  24   7   7      IVS
XFOR  11   6   6   1  24   6   6      STRAINER
ZFOR  12   7  14   1  24  10  10      BAFFLE
ZFOR  13   5   6   1  24   8  10      REFL
ZFOR  94   1   4   1  24   8  10
ZFOR  14   8   9   1  24   5   5      CB INLET
XFOR  15   1   6   1  24  11  11      ABOVE CORE
END
 &STRUCT
 NSTRUC=60,
 NTSEL=44*1,4*3,6*2,6*8,
 NTSMAT=42*2,2*1,4*1,6*1,6*1,
 OUTR=42*0.00292,2*0.0127,0.1345,0.1488,0.1619,0.1740,
      4*0.00292,2*0.0127,3*.659,3*.729,
 RODFR=63.3,9.06,4*63.3,217,217,162.75,162.75,217,217,217,108.5,
       217,217,162.75,162.75,
       108.5,108.5,217,217,108.5,108.5,217,217,108.5,108.5,217,217,
       6*272.25,162.75,3*272.25,162.75,272.25,
       33.625,118.833,4*24.0,1302,4557,3906,6076,33.625,118.833,
       6*1,
 IHTSTR=60*1,
 HYDRAD=42*0.00292,2*0.0127,0.1345,0.1488,0.1619,0.1740,4*0.00292,
        2*0.0127,3*0.659,3*0.729,
 IXYZ=60*3,
 NTSADJ=6*4,36*2,2*24,4*24,6*24,6*4,
 NTSMAT=42*2,2*1,4*1,6*1,6*1,
 MATERL=2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,
        2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,
        2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,
        2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,
        2,1,2,1,18*1,
 NMPAR=2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,
       2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,
       2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,
       2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,2,3,
       2,3,2,3,18*5,
 DRPAR=1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
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       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
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       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
       1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
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      1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
      1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
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      1.905E-4,8.21267E-4,1.905E-4,8.21267E-4,
     2*0.00254,0.0269,0.02976,0.03233,0.0348,
     4*5.84E-4,2*0.00254,3*0.1318,3*0.1453,
NSAPTY=1,SGAP=7.622E-5,NGAP=7297,IGAP=42*1,18*0,
QSPAR=1.079E8,1.748E9,1.099E8,1.8025E9,
      1.945E8,1.6976E9,1.084E8,1.715E9,
      1.983E8,1.716E9,1.139E8,1.740E9,
      9.19E7,1.777E9,1.15E8,1.427E9,
      9.505E7,1.561E9,9.550E7,1.557E9,
      8.860E7,1.418E9,9.025E7,1.422E9,
      1.010E8,1.566E9,1.021E8,1.634E9,
      1.106E8,1.441E9,9.090E7,1.419E9,
      9.835E7,1.562E9,9.853E7,1.567E9,
      8.419E7,1.379E9,8.350E7,1.372E9,
      9.319E7,1.508E9,1.150E8,1.501E9,
      8.087E7,1.345E9,7.795E7,1.301E9,
      8.922E7,1.496E9,9.49E7,1.561E9,
      8.250E7,1.376E9,7.895E7,1.317E9,
      8.793E7,1.438E9,9.358E7,1.504E9,
      7.000E7,1.148E9,6.910E7,1.145E9,
      7.236E7,1.173E9,7.365E7,1.194E9,
      6.691E7,1.110E9,6.23E7,1.051E9,
      6.940E7,1.171E9,7.865E7,1.293E9,
      6.847E7,1.140E9,6.480E7,1.082E9,
      6.339E7,1.045E9,7.544E7,1.214E9,
      1.244E7,4.053E6,16*0.0,
&END
  1   1   1   2   5   8   8          REGION 1
  2   1   1   6   9   8   8          RGION 2
  3   1   1  10  13   8   8          REGION 1
  4   1   1  14  17   8   8
  5   1   1  18  21   8   8
  6   1   1  22  24   8   8
  6   1   1   1   1   8   8
  7   2   2   2   3   8   8
  8   2   2   4   5   8   8
  9   2   2   6   7   8   8
 10   2   2   8   9   8   8
 11   2   2  10  11   8   8
 12   2   2  12  13   8   8
 13   2   2  14  15   8   8
 14   2   2  16  17   8   8
 15   2   2  18  19   8   8
 16   2   2  20  21   8   8
 17   2   2  22  23   8   8
 18   2   2  24  24   8   8
 18   2   2   1   1   8   8
 19   3   3   2   3   8   8
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20	3	3	4	5	8	8
21	3	3	6	7	8	8
22	3	3	8	9	8	8
23	3	3	10	11	8	8
24	3	3	12	13	8	8
25	3	3	14	15	8	8
26	3	3	16	17	8	8
27	3	3	18	19	8	8
28	3	3	20	21	8	8
29	3	3	22	23	8	8
30	3	3	24	24	8	8
30	3	3	1	1	8	8
31	4	4	2	3	8	8
32	4	4	4	5	8	8
33	4	4	6	7	8	8
34	4	4	8	9	8	8
35	4	4	10	11	8	8
36	4	4	12	13	8	8
37	4	4	14	15	8	8
38	4	4	16	17	8	8
39	4	4	18	19	8	8
40	4	4	20	21	8	8
41	4	4	22	23	8	8
42	4	4	24	24	8	8
42	4	4	1	1	8	8
43	5	5	1	24	8	8
44	6	6	1	24	8	8
45	7	7	1	24	8	10
46	8	8	1	24	8	10
47	9	9	1	24	8	10
48	10	10	1	24	8	10
49	1	1	1	24	9	10
50	2	2	1	24	9	10
51	3	3	1	24	9	10
52	4	4	1	24	9	10
53	5	5	1	24	9	10
54	6	6	1	24	9	10
55	6	6	6	6	11	11
55	8	8	6	6	11	11
55	7	7	5	5	11	11
55	7	7	7	7	11	11
55	6	6	6	6	12	12
55	8	8	6	6	12	12
55	7	7	5	5	12	12
55	7	7	7	7	12	12
55	6	6	6	6	13	13
55	8	8	6	6	13	13
55	7	7	5	5	13	13
55	7	7	7	7	13	13
55	6	6	6	6	14	14
55	8	8	6	6	14	14
55	7	7	5	5	14	14
55	7	7	7	7	14	14
55	6	6	6	6	15	15
55	8	8	6	6	15	15

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55	6	6	6	6	16	16
55	8	8	6	6	16	16
55	7	7	5	5	16	16
55	7	7	7	7	16	16
55	6	6	6	6	17	17
55	8	8	6	6	17	17
55	7	7	5	5	17	17
55	7	7	7	7	17	17
55	6	6	6	6	18	18
55	8	8	6	6	18	18
55	7	7	5	5	13	18
55	7	7	7	7	18	18
56	6	6	14	14	11	11
56	8	8	14	14	11	11
56	7	7	13	13	11	11
56	7	7	15	15	11	11
56	6	6	14	14	12	12
56	8	8	14	14	12	12
56	7	7	13	13	12	12
56	7	7	15	15	12	12
56	6	6	14	14	13	13
56	8	8	14	14	13	13
56	7	7	13	13	13	13
56	7	7	15	15	13	13
56	6	6	14	14	14	14
56	8	8	14	14	14	14
56	7	7	13	13	14	14
56	7	7	15	15	14	14
56	6	6	14	14	15	15
56	8	8	14	14	15	15
56	7	7	13	13	15	15
56	7	7	15	15	15	15
56	6	6	14	14	16	16
56	8	8	14	14	16	16
56	7	7	13	13	16	16
56	7	7	15	15	16	16
56	6	6	14	14	17	17
56	8	8	14	14	17	17
56	7	7	13	13	17	17
56	7	7	15	15	17	17
56	6	6	14	14	18	18
56	8	8	14	14	18	18
56	7	7	13	13	18	18
56	7	7	15	15	18	18
57	6	6	22	22	11	11
57	8	8	22	22	11	11
57	7	7	21	21	11	11
57	7	7	23	23	11	11
57	6	6	22	22	12	12
57	8	8	22	22	12	12
57	7	7	21	21	12	12
57	7	7	23	23	12	12
57	6	6	22	22	13	13

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57	8	8	22	22	13	13
57	7	7	21	21	13	13
57	7	7	23	23	13	13
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58	7	7	2	2	18	18
58	9	9	2	2	18	18
58	8	8	1	1	18	18
58	8	8	3	3	18	18

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60	9	9	18	18	15	15
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60	8	8	19	19	15	15
60	7	7	18	18	16	16
60	9	9	18	18	16	16
60	8	8	17	17	16	16

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FILE: FFTFFG DATA A AHL VH/CHS LEVEL 102

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 60   9   9  18  18  17  17
 60   8   8  17  17  17  17
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 60   7   7  18  18  18  18
 60   9   9  18  18  18  18
 60   8   8  17  17  18  18
 60   8   8  19  19  18  18
END
TL    360.0        1  14   1  24   1   7
TL    800.0        1  14   1  24  11  18
TL    800.0        1   6   1  24   8  10
TL    360.0        7  14   1  24   8  10
ALZ   0.353        1   1   1   5   7  10
ALZ   0.0883       1   1   6   9   7  10
ALZ   0.353        1   1  10  24   7  10
ALZ   0.2299       2   2   1   1   7  10
ALZ   0.2824       2   2   2   5   7  10
ALZ   0.2299       2   2   6   9   7  10
ALZ   0.2824       2   2  10  13   7  10
ALZ   0.2918       2   2  14  15   7  10
ALZ   0.168        2   2  16  17   7  10
ALZ   0.2824       2   2  18  21   7  10
ALZ   0.2299       2   2  22  24   7  10
ALZ   0.3533       3   3   1   1   7  10
ALZ   0.1766       3   3   2   5   7  10
ALZ   0.3533       3   3   6   9   7  10
ALZ   0.1766       3   3  10  13   7  10
ALZ   0.3533       3   3  14  17   7  10
ALZ   0.1766       3   3  18  21   7  10
ALZ   0.3533       3   3  22  24   7  10
ALZ   0.3533       4   4   1  13   7  10
ALZ   0.2119       4   4  14  15   7  10
ALZ   0.3533       4   4  16  21   7  10
ALZ   0.2119       4   4  22  23   7  10
ALZ   0.3533       4   4  24  24   7  10
ALZ   0.0935       5   5   1  24   7  10
ALZ   0.1266       6   6   1  24   7  10
ALZ   0.015        7  10   1  24   7  10
ALZ   0.010       11  14   1  24   7  10
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AL    0.353        1   1   1   5   7  10
AL    0.0883       1   1   6   9   7  10
AL    0.353        1   1  10  24   7  10
AL    0.2299       2   2   1   1   7  10
AL    0.2824       2   2   2   5   7  10
AL    0.2299       2   2   6   9   7  10
AL    0.2824       2   2  10  13   7  10
AL    0.2918       2   2  14  15   7  10
AL    0.168        2   2  16  17   7  10
AL    0.2824       2   2  18  21   7  10
AL    0.2299       2   2  22  24   7  10
AL    0.3533       3   3   1   1   7  10
AL    0.1766       3   3   2   5   7  10
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AL	0.1766	3	3	10	13	7	10	
AL	0.3533	3	3	14	17	7	10	
AL	0.1766	3	3	18	21	7	10	
AL	0.3533	3	3	22	24	7	10	
AL	0.3533	4	4	1	13	7	10	
AL	0.2119	4	4	14	15	7	10	
AL	0.3533	4	4	16	21	7	10	
AL	0.2119	4	4	22	23	7	10	
AL	0.3533	4	4	24	24	7	10	
AL	0.0935	5	5	1	24	7	10	
AL	0.1266	6	6	1	24	7	10	
AL	0.015	7	10	1	24	8	10	
AL	0.010	11	14	1	24	8	10	
ALX	0.0	1	6	1	24	7	7	
ALY	0.0	1	6	1	24	7	7	
ALX	0.0	1	10	1	24	8	10	
ALY	0.0	1	10	1	24	8	10	
ALX	0.1237	6	6	1	24	6	6	
ALX	0.0	6	6	1	24	7	7	
ALZ	0.8466	8	9	1	1	5	5	C BASKET INLET
ALZ	0.8466	8	9	3	3	5	5	
ALZ	0.8466	8	9	5	5	5	5	
ALZ	0.8466	8	9	7	7	5	5	
ALZ	0.8466	8	9	9	9	5	5	
ALZ	0.8466	8	9	11	11	5	5	
ALZ	0.8466	8	9	13	13	5	5	
ALZ	0.8466	8	9	15	15	5	5	
ALZ	0.8466	8	9	17	17	5	5	
ALZ	0.8466	8	9	19	19	5	5	
ALZ	0.8466	8	9	21	21	5	5	
ALZ	0.8466	8	9	23	23	5	5	
ALZ	0.0	8	9	2	2	5	5	C B INLET
ALZ	0.0	8	9	4	4	5	5	C B INLET
ALZ	0.0	8	9	6	6	5	5	C B INLET
ALZ	0.0	8	9	8	8	5	5	C B INLET
ALZ	0.0	8	9	10	10	5	5	C B INLET
ALZ	0.0	8	9	12	12	5	5	C B INLET
ALZ	0.0	8	9	14	14	5	5	C B INLET
ALZ	0.0	8	9	16	16	5	5	C B INLET
ALZ	0.0	8	9	18	18	5	5	C B INLET
ALZ	0.0	8	9	20	20	5	5	C B INLET
ALZ	0.0	8	9	22	22	5	5	C B INLET
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ALZ	0.0	10	10	1	24	5	5	C B INLET
ALZ	0.0	1	6	1	24	4	4	LPLNM WALL
ALZ	0.0	1	6	1	24	5	5	LPLNM WALL
ALZ	0.0	11	14	1	24	6	6	CSS
ALX	0.0	10	10	1	24	6	6	CSS WALL
ALX	0.0	6	6	1	24	5	5	LPLNM SIDE WALL
AL	0.4093	1	4	1	24	11	12	IT IN UPPER PLNM
AL	0.9145	1	4	1	24	14	18	FLOW TUBES
AL	0.8748	1	4	1	24	13	13	FLOW TUBES
ALZ	0.8748	1	4	1	24	13	13	FLOW TUBES

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ALZ	0.9145	1	4	1	24	14	18	FLOW TUBES
ALZ	0.940	5	6	1	24	14	18	FLOW TUBES
AL	0.940	5	6	1	24	13	18	FLOW TUBES
AL	0.1305	5	6	1	24	11	12	FLOW TUBES
ALX	0.0	1	6	1	24	12	12	IT OVER CORE
ALX	0.1818	1	6	1	24	11	11	OPEN GAP
ALY	0.0	1	6	1	24	11	12	IT OVER CORE + RFL
ALZ	0.4033	1	4	1	24	11	12	IT OVER CORE
ALZ	0.1305	5	6	1	24	11	12	IT OVER RFL
ALX	0.0	7	8	6	6	11	18	IT STEM
ALX	0.0	7	8	14	14	11	18	IT STEM
ALX	0.0	7	8	22	22	11	18	IT STEM
ALY	0.0	8	8	5	6	11	18	
ALY	0.0	8	8	13	14	11	18	
ALY	0.0	8	8	21	22	11	18	
ALY	0.5	9	9	5	6	11	18	
ALY	0.5	9	9	13	14	11	18	
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ALZ	0.5	9	9	14	14	11	18	
ALZ	0.5	9	9	22	22	11	18	
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AL	0.5	9	9	14	14	11	18	
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ALZ	0.0	9	9	2	2	12	18	IVHM STEM
ALZ	0.0	9	9	10	10	12	18	
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AL	1.0	9	9	2	2	12	18	
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AL	1.0	9	9	18	18	12	18	
ALX	0.0	8	9	2	2	12	18	IVHM STEM
ALX	0.0	8	9	10	10	12	18	IVHM STEM
ALX	0.0	8	9	18	18	12	18	
ALY	0.0	9	9	1	2	12	18	
ALY	0.0	9	9	9	10	12	18	
ALY	0.0	9	9	17	18	12	18	
ALZ	0.5570	10	10	2	2	12	12	CELL 8 OF IVHM,
ALZ	0.5570	10	10	10	10	12	12	
ALZ	0.5570	10	10	18	18	12	12	
AL	0.966	10	10	2	2	12	12	
AL	0.966	10	10	10	10	12	12	
AL	0.966	10	10	18	18	12	12	
ALX	0.945	10	10	2	2	12	12	IVHM BOTTOM PLATE CELL 8
ALX	0.945	10	10	10	10	12	12	IVHM BOTTOM PLATE
ALX	0.945	10	10	18	18	12	12	
ALY	0.903	10	10	1	2	12	12	
ALY	0.903	10	10	9	10	12	12	
ALY	0.903	10	10	17	18	12	12	
ALZ	0.5186	11	11	2	2	12	12	IVHM TOE ASSY

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```
ALZ     0.5186   11  11  10  10  12  12
ALZ     0.5186   11  11  18  18  12  12
AL      0.778    11  11   2   2  12  12
AL      0.778    11  11  10  10  12  12
AL      0.778    11  11  18  18  12  12
ALX     0.5717   11  11   2   2  12  12
ALX     0.5717   11  11  10  10  12  12
ALX     0.5717   11  11  18  18  12  12
ALY     0.2493   11  11   1   2  12  12
ALY     0.2493   11  11   9  10  12  12
ALY     0.2493   11  11  17  18  12  12
ALZ     0.8      11  11   2   2  13  18    IVHM TOE ASSY
ALZ     0.8      11  11  10  10  13  18
ALZ     0.8      11  11  18  18  13  18
AL      0.8      11  11   2   2  13  18
AL      0.8      11  11  10  10  13  18
AL      0.8      11  11  18  18  13  18
ALX     0.6186   11  11   2   2  13  18
ALX     0.6186   11  11  10  10  13  18
ALX     0.6186   11  11  18  18  13  18
ALY     0.3315   11  11   1   2  13  18
ALY     0.3315   11  11   9  10  13  18
ALY     0.3315   11  11  17  18  13  18
ALZ     0.422     1   3   1  24  13  13     IT.TUBES
ALZ     0.422     4   6   1  24  14  14
ALZ     0.2647    7   7   6   6  14  18
ALZ     0.2647    7   7  14  14  14  18
ALZ     0.2647    7   7  22  22  14  18
AL      0.2647    7   7   6   6  14  18
AL      0.2647    7   7  14  14  14  18
AL      0.2647    7   7  22  22  14  18
END
//GO.FT10F001 DD DSN=B29328.FFTFFGN.RESTART,DISP=(NEW,CATLG),
//  UNIT=TEMP,SPACE=(TRK,(20,10),RLSE)
//GO.FT76F001 DD DUMMY
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```

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